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Indoor Air Quality Model Version 1.0

by

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Air Cleaners	Indoor Air	13A, 13I
Air Conditioning	Air Quality	
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ABSTRACT

A multi-room model for estimating the impact of various sources on indoor air quality (IAQ) is presented. The model is written for use on IBM-PC and compatible microcomputers. The model is easy to use with a menu driven user interface. Data entry is handled with a "fill in a form" interface. Model results are presented in graphical and tabular form. The model treats each room as a well mixed chamber that can contain both sources and sinks. The model allows analysis of the impact of inter-room air flows, heating ventilating air conditioning (HVAC) air flows, and air cleaners on IAQ. Model predictions are compared with experimental data from the EPA IAQ test house. The model predictions are in good agreement with the experimental data. The model is a useful tool for analyzing IAQ issues.

The model requires an IBM-PC or compatible computer, DOS 2.1 or higher, 1 disk drive, and at least 512 k-bytes of memory. A graphics adapter and monitor are required to display the graphical output from the model.

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SECTION 1.
MODEL OVERVIEW

Introduction

This model provides an analysis tool for those involved in indoor air problems. The model allows rapid analysis of pollutant migration in a building under specified air flow conditions. The model calculations have been compared with limited experimental data and with predictions of other models. These comparisons have been favorable. These comparisons show that the model is calculating properly and that the predictions are in line with the experimental data.

Additional work is necessary to fully validate the model.

The Problem

Indoor air quality is determined by the interactions of sources, sinks, and air movement between rooms and between the building and the outdoors. Sources may be located in rooms, in the HVAC system, or outside the building. Sinks may be located in the same locations. Sinks may also act as sources when the pollutant concentrations drop below a given value.

Air movement in a building consists of:

1. Natural air movement between rooms.
2. Air movement driven by a forced air system (HVAC).
3. Air movement between the building and the outdoors.

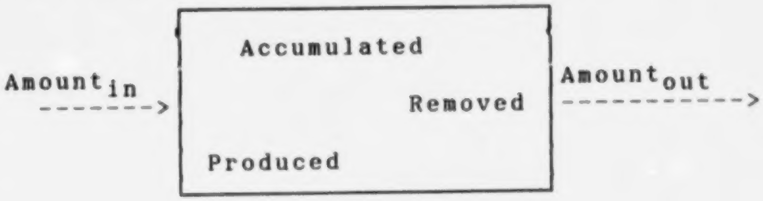


Figure 1-1. Single room flows.

The pollutant concentration in a room is given by a mass balance of the various pollutants flows. For the single room shown in Figure 1-1:

Amount in - Amount out + Amount produced - Amount removed = Amount accumulated

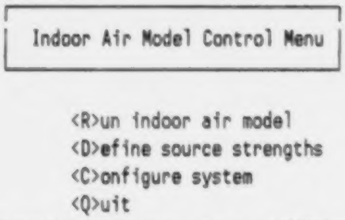
The analysis can be extended to multiple rooms by writing a system of equations for each room. The amount of air entering a room from all sources (the HVAC, outdoors, and other rooms) must equal the amount of air leaving the room.

The mass balance equations for a building result in a series of linear ordinary differential equations. These equations can be solved with standard techniques. The current version of the AEERL model uses a modified midpoint method given by Press et al. (1987). This technique is somewhat faster than a fourth order Runge Kutta numerical solution. The technique uses a fixed time step. The method appears to be both accurate and stable when the time steps are not too large.

The User Interface

The AEERL model uses a menu-driven data-input user interface and a graphics-output user interface. This user interface is easy to use and self prompting. The user interface allows the user to change the input parameters quickly and easily and allows rapid analysis of the calculated results.

A master menu controls the operation of the program. The master menu is shown in Figure 1-2.



Indoor Air Model Control Menu

<R>un indoor air model
<D>efine source strengths
<C>onfigure system
<Q>uit

Figure 1-2. Master menu for AEERL indoor air model.

The model can be configured for an IBM-PC, XT, AT, or compatible. The model can run on a computer with a monochrome adapter, a color graphics adapter (CGA), or an enhanced graphics adapter (EGA). When the model is run with a monochrome adapter, all graphics are disabled.

Using the Manual

The manual is divided into six sections. Section 1 (this section) is a brief overview of the entire model. Section 2 discusses the theory of the model and the numerical techniques used in the computer program. Section 3 provides user instructions for running the model. Section 4 provides several case studies and examples to help in using the model. Section 5 provides an extended case study based on research conducted in the AEERL test house. And Section 6 provides hints on using the model.

Getting Started

Making a backup copy

The program is distributed on one disk. The files on this disk are: INDOOR.EXE, CONFIG.IND, HELP.IND, DEFAULT.ROM, POLLUTIO.DAT, INDOOR.BAT, README.BAT, HURRY.BAT, INSTALL.BAT, READ.ME, README.TOO, and FASTSTAR.DOC. You should make a backup copy of the disk. The backup copy can be made using the DOS DISKCOPY command. If you have two floppy disk drives, place the distribution disk in drive A and a blank disk in drive B. Type DISKCOPY A: B: and follow the on-screen instructions. If you have one floppy disk drive, place the distribution disk in the drive and type DISKCOPY A: A:, and follow the on-screen instructions.

After you have made the backup, place the distribution disk in a safe place and work with the copy you made.

Installing on hard disk system

If you are installing the model on a computer with a hard disk, you can use the install procedures contained on the distribution disk. Place the backup copy of the distribution disk in the floppy disk. Make the floppy disk the active drive. Type INSTALL and let the computer do the work.

The install procedure creates a subdirectory on your hard disk called INDOOR. The procedure then copies the files INDOOR.EXE, CONFIG.IND, HELP.IND, DEFAULT.ROM, and POLLUTIO.DAT from the floppy disk to the subdirectory. The install procedure then copies the file INDOOR.BAT to the root directory.

If you wish to install the program yourself, you should create a subdirectory for the program and copy the following files to the subdirectory: INDOOR.EXE, CONFIG.IND, HELP.IND, DEFAULT.ROM, and POLLUTIO.DAT.

If you use the install procedure you can execute the program by typing INDOOR from the DOS prompt at the root directory. This activates the INDOOR.BAT procedure which switches from the root directory to the indoor subdirectory and then loads the indoor air quality model. If you have a PATH to the root directory, you can execute the INDOOR.BAT file from any subdirectory.

Installing on floppy disk system

If you have a floppy disk system, create a working copy of the program by placing the distribution disk in drive A and a blank formatted disk in drive B. Then type the following commands from the DOS prompt:

```
 copy a:*.exe b:
(wait until disk drive stops then type)
copy a:*.ind b:
(wait until disk drive stops then type)
copy a:*.rom b:
(wait until disk drive stops then type)
copy a:*.dat b:
```

NOTE: Do not type until disk drive stops.

To run the program, make the disk drive containing the program the active drive and then type INDOOR and press ENTER.

In a hurry

If you are in a hurry to run the model, read the README files on the distribution disk. You can read these files by 1) making the disk drive with the distribution disk the active drive and 2) typing README from the DOS prompt. The README files are also given in Appendix B of this manual.

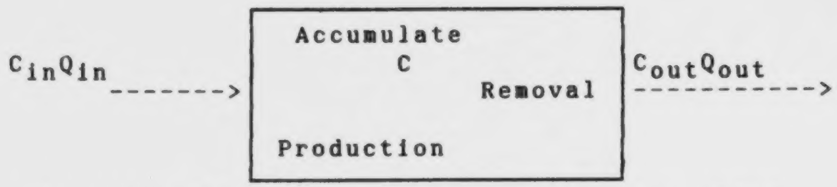
The README files and the FASTSTAR.DOC file contain sufficient information to allow you to run the program.

SECTION 2.
THEORY AND NUMERICAL TECHNIQUES

Theory

Mass balances

The pollutant flows into and out of a building can be described as shown in Figure 2-1.



C refers to concentrations and Q refers to flow rates.

Figure 2-1. Mass balance for a single room.

These pollutant flows can be described by the mass balance equation

$$\mathrm{Mass}_{in} + \mathrm{Mass}_{produced} - \mathrm{Mass}_{out} - \mathrm{Mass}_{removed} = \mathrm{Mass}_{accumulated}$$

where Mass_{in} is the mass entering the building, Mass_{out} is the mass leaving the building, $\mathrm{Mass}_{produced}$ is the mass produced in the building (source), $\mathrm{Mass}_{removed}$ is the mass removed in the building (sink), and $\mathrm{Mass}_{accumulated}$ is the mass accumulated in the building. ($\mathrm{Mass}_{in} = C_{in}Q_{in}$, $\mathrm{Mass}_{out} = C_{out}Q_{out}$ etc.)

This equation holds for the building as a whole and for each room in the building. For example, for a building with two rooms, the mass balances are:

Room 1

$$\mathrm{Mass}_{in1} + \mathrm{Mass}_{produced1} - \mathrm{Mass}_{out1} - \mathrm{Mass}_{removed1} = \mathrm{Mass}_{1}$$

Room 2

$$\mathrm{Mass}_{in2} + \mathrm{Mass}_{produced2} - \mathrm{Mass}_{out2} - \mathrm{Mass}_{removed2} = \mathrm{Mass}_{2}$$

where Mass_1 is the mass accumulated in Room 1 and Mass_2 is the mass accumulated in Room 2.

And for the whole building:

$$\mathrm{Mass}_{in1} + \mathrm{Mass}_{in2} + \mathrm{Mass}_{produced1} + \mathrm{Mass}_{produced2} - \mathrm{Mass}_{out1} - \mathrm{Mass}_{out2} - \mathrm{Mass}_{removed1} - \mathrm{Mass}_{removed2} = \mathrm{Mass}_{B}$$

where Mass_B is the mass accumulated in the building.

Mixing

The type of mixing between the pollutant and the room air must be specified before the mass balance equations can be used in a model. Because mixing is a complex phenomenon, the exact mixing cannot be specified; simplifying assumptions must be made. Plug flow mixing and well mixed mixing are two common mixing possibilities.

In the plug flow mixing model the pollutant concentration varies from point to point along the air flow path. In the well mixed model the pollutant concentration is the same for every point in the room.

The current model uses the well mixed model. This model was selected because data from the AEERL test house indicated that pollutant concentrations within a room do not vary significantly. Table 2-1 shows the baseline data from the AEERL test house that indicate that the test house is well mixed.

Table 2-1. Baseline data for IAQ test house.

Probe Location & height	CO ppm	CO_2 ppm	NO_x ppm	THC(as carbon) ppm
Outdoors	1.14	398	0.06	0.09
Den 15.24 cm	1.21	422	0.06	0.10
Den 91.44 cm	1.24	436	0.06	0.10
Den 162.60 cm	1.23	438	0.06	0.10
Den 238.80 cm	1.24	439	0.06	0.10
Average den	1.23	434	0.06	0.10
Bedroom 15.24 cm	1.22	455	0.06	0.09
Bedroom 91.44 cm	1.20	442	0.06	0.09
Bedroom 162.60 cm	1.11	393	0.06	0.09
Bedroom 238.80 cm	1.11	393	0.06	0.09
Average bedroom	1.16	421	0.06	0.09

Section 4 of this report discusses ways of dealing with situations where the well mixed model is not appropriate.

Final equations

If we accept the well mixed model, we can write a differential equation for the mass balance equation for a room:

$$VdC/dt = C_{in}Q_{in} - C_{out}Q_{out} + S - R$$

by the well mixed assumption, $C_{out} = C$ and the equation can be rewritten as

$$VdC/dt = C_{in}Q_{in} - CQ_{out} + S - R$$

where V is the volume of the room, C_{in} is the pollutant concentration entering the room, Q_{in} is the air flow entering the room, Q_{out} is the air flow leaving the room, S is the source term, and R is the removal term.

For a two room model with air entering Room 1 from Room 2 and the outdoors and with air entering Room 2 from Room 1 and the outdoors, we have the following set of equations:

Room 1

$$V_1dC_1/dt = Q_{2-1}C_2 + Q_oC_{0-1} - C_1Q_{1-2} - C_1Q_{1-0} + S_1 - R_1$$

Room 2

$$V_2dC_2/dt = Q_{1-2}C_1 + Q_oC_{0-2} - C_2Q_{2-1} - C_2Q_{2-0} + S_2 - R_2$$

With the air mass balances:

$Q_{0-1} + Q_{2-1} - Q_{1-0} - Q_{1-2} = 0$ and

$Q_{0-2} + Q_{1-2} - Q_{2-0} - Q_{2-1} = 0$

where C_1 and C_2 are the concentrations in Rooms 1 and 2, respectively, Q_{1-2} is the air flow from Room 1 to Room 2, Q_{1-0} is the air flow from Room 1 to the outdoors, Q_{0-1} is the air flow from the outdoors to Room 1, Q_{0-2} is the air flow from the outdoors to Room 2, Q_{2-1} is the air flow from Room 2 to Room 1, and Q_{2-0} is the air flow from Room 2 to the outdoors.

The system of equations can be extended to any number of rooms. An HVAC system can be added by treating the HVAC as a room. (All the continuity equations that hold for the individual rooms also must hold for the HVAC.) Because a wide range of pollutant concentrations can enter the HVAC system from various points, the well mixed model might not fit the HVAC system as well as it does individual rooms. If the pollutant concentrations entering the HVAC system from various rooms are very different, it might be appropriate to model the HVAC as a number of small rooms.

Numerical Techniques

The various mass balances discussed above lead to a set of linear differential equations. These equations can be solved with many different techniques. The best known is a fourth order Runge Kutta technique. Press et al. (1987) present a midpoint method as an alternative to Runge Kutta. Both techniques were programmed and the midpoint method was faster. Therefore, the midpoint method was used in the final version of the program. The reader interested in the details of the midpoint method should consult Press et al.

The midpoint technique stability and accuracy are equivalent to those of the Runge Kutta technique. This means that the midpoint method will be stable and accurate, if the time step is small enough. The stability and accuracy of the method in the context of the indoor air model were investigated over a wide range of situations. The results of model runs were compared with results from analytical calculations, other indoor air models, and model runs with differing step sizes. The conclusions reached from these studies are:

1. When the room volumes are of about the same size, large time steps (from 30 to 120 seconds) can be used with little difficulty (unless the source and sink terms exhibit short term time behavior).
2. When the room volumes differ by orders of magnitude, as is possible when an HVAC system is included in the model, small time steps (20 to 30 seconds or less) are needed to avoid numerical instabilities.
3. When the model solutions were stable, the solutions were also accurate.

A time step of 30 seconds works well in most situations. If the time step is too large, the solution becomes unstable. The program monitors the solution to detect the onset of numerical instability. When instability is detected, the program stops all calculations and prints a warning message with instructions to reduce the time step. The program provides a suggested value for the new time step. Note, however, that the program may crash in spite of the error checking provided by the program.

Source Terms

A wide range of source terms is necessary to model indoor sources of pollution. Possible source characteristics include random on/off sources (cigarettes), sources that are on for a specified period of time (heaters), steady state sources (moth crystals), and sources with high initial emission rates followed by low steady state (floor wax). The AEERL model accommodates all of these possibilities in an idealized fashion.

Each type of source behavior is represented by a type of source. For example, the random on/off source is represented by cigarette smoking. Each of the sources in the model is discussed below.

Cigarette smoking

Cigarette smoking is modeled as a random event with from 1 to n cigarettes smoked per hour. The cigarette is turned on at some random time during the hour. A second cigarette is not allowed on until the first cigarette is smoked. Multiple smokers are accommodated in the model. However, all smokers smoke at the same time. Personal observations indicated that this is a reasonable assumption about the habits of multiple smokers. If one person starts smoking, other smokers tend to light up too.

A simple random number generator is used to determine if a cigarette is on or off. Because of the random nature of this source, it is possible to have more or fewer cigarettes smoked in a specific hour than specified.

The emission factors for cigarette are based on data in the Indoor Air Data Base and are shown in Table 2-2.

Table 2-2. Emission factors for smoking

Pollutant	Emissions mg/cigarette
Particulate	24
CO	10.33
CO_2	38.45

Kerosene heaters

Kerosene heaters are a common source of indoor air pollution. These heaters are modeled as steady state on/off heaters. The on and off times are part of the data input to the program. Up to three on/off cycles per day are allowed.

The emission factors for kerosene heaters are based on work conducted by AEERL and are shown in Table 2-3.

Table 2-3. Emission factors for kerosene heaters

	Emissions μg/kJ	
Pollutant	Dual radiant	Convective
Particulate	4.8	0.98
CO	No data	17.
CO_2	No data	63.
NO_x	20	20.
VOC	No data	

Unvented gas heaters

Unvented gas heaters are another common on/off source of indoor air pollution. These heaters are modeled like kerosene heaters.

The emission factors for unvented heaters are based on data from the Indoor Air Data Base and are shown in Table 2-4.

Table 2-4. Emission factors for unvented gas heaters

Pollutant	Emission factor µg/kJ
Particulate	0.20
CO	1 - 10
CO_2	51,000
NO_x	15
VOC	No data

Moth crystals

Moth crystals can be an important source of VOC emissions indoors. Moth crystals are long term steady state sources. The emissions from moth crystals are a function of temperature and the surface area of the crystals.

The emission factors are based on work conducted by AEERL and equal 1.4 $mg/h/cm^2$ of exposed surface.

Floor wax

Floor wax is an example of a "wet" source of VOC emissions. Wet sources initally have a high emission factor, followed by a low level steady state emission factor.

The emission factor for floor wax is based on data in Tichenor et al. (1987) as shown in Figure 2-2. The curves in Figure 2-2 can be approximated by equations of the form:

$$\text{emission} = a1 + a2\ln(t) + a3\ln(t)^2$$

where a1, a2, and a3 are constants.

Other

The other source is provided as a user defined steady state source. The source cannot be turned off.

Sinks

It is generally recognized that walls and furnishings can serve as collectors (sinks) of indoor air pollutants. The model allows investigation of the behavior of sinks by providing a single sink that is a function of the surface area of the walls in the room. This sink may be either a pure sink (i.e., pollutants trapped by the sink are not reemitted) or a reemitting sink.

For a pure sink, the amount of material per unit time removed by the sink, R_s, is

$$R_s = K_{sink} area_{room} C_{room}$$

where K_{sink} is a user specified constant, $area_{room}$ is the wall area of the room, and C_{room} is the concentration in the room. For a reemitting sink, the amount emitted per unit time is assumed to be:

$$M_{emitted} = K_{emitt}(C_{room} - C_{crit}) sink_{mass} area_{room}$$

where K_{emitt} is a user specified constant, C_{crit} is the concentration at which reemission starts, and $sink_{mass}$ is the total mass of material collected in the sink.

Reasonable values of the sink constant are 0.15 to 0.25 m/h.

The removal of pollutants by sinks can be described as a two step process. First the pollutants are transported to the sink. Second the pollutants are collected by the sink with a finite efficiency. Or in equation form:

$$R_s = eM_s$$

where e is the efficiency of removal and M_s is the mass hitting the sink per unit time. If e is 1, then $M_s = R_s$.

The mass transport to the wall is dominated by the diffusion. Convection acts to move gas to the boundary layer, but diffusion transports the gas to the wall. If we assume that the movement of gas to the wall is dominated by diffusion, the mass transport to the sink, M_s, per area of the wall per unit time is given by:

$$M_s = 2C_{room} (D/\pi)^{1/2}$$

where D is the diffusivity of the gas. The term $2(D/\pi)^{1/2}$ is the sink constant, K_{sink}.

The diffusivities of most gases in air range from 0.02 to 0.04 m^2/h. For a pure sink that has a capture efficiency of 1, K_{sink} ranges from 0.16 to 0.25 m/h. This is in fair agreement with the sink constant required to fit the limited experimental data on sink effects.

The Air Handling System

Informal discussions with professionals in the design of ventilating systems for commercial and residential buildings and measurements in the AEERL test house indicate that the air flow generated by an air handling system is several times larger than natural air flows. Thus when an HVAC system is on, the building air flows are dominated by the HVAC.

Air flow patterns in a building with the air handling system on may be significantly different from those in the same building with the air handling system off. For example, many houses have a single return vent for the air handling system. When the air handling system is on, air flow is dominated by the flow to the return vent. When the air handling system is off, air flow is less directed.

The on/off behavior of the air handling system is modeled by allowing two different air flow patterns to exist in the building. One pattern (Case 1) is active when the air handling system is on, and the other (Case 2) is active when the air handling system is off. The model switches between these two patterns depending on the state of the air handling system. The state of the air handling system (on or off) is determined by a random number generator designed to ensure that the air handling system is on for a specified fraction of each hour. The air handling system may switch from on to off and back several times in an hour.

The function that switches the HVAC on or off is designed to ensure that the HVAC state (on or off) does not change from on to off or vice versa in rapid sucession. After the state of the HVAC changes, it stays at the new state for a set number of time steps in the model. This forcing the HVAC to remain at one state for a set time reduces the random nature of switching.

This random switching from on to off and back appears to provide good modeling of actual air handling system behavior.

The two air flow patterns provided by the model can be used for changes in air flow due to causes other than HVAC on or off. For example, Case 1 might be used to describe the air flow pattern with a door open and Case 2 to describe the air flow pattern with the same door closed.

Programming the Model

The model is written in Microsoft QuickBasic 4.0 for the IBM-PC and compatible family of microcomputers. This language is similar to the interpreted Basic that comes with most MS-DOS computers. However, it has many features not present in the interpreted version of the model. The language is mostly compatible with TurboBasic from Borland International.

The main features of the language which are different from the interpreted version are:

block if/then/else statements
numerous looping structures
select case
multiple line user defined functions
subroutines that are isolated from the program
local and global variables
line numbers are not required
programs can be larger than 64 k-bytes

All of these features of the language are used in the program.

Note that the program on the disk is a compiled program and does not require QuickBasic to run. QuickBasic is required to modify the model.

User interface

The user interface is the portion of the program that most tightly ties the program to the IBM-PC standard. The user interface uses BIOS call and writes directly to the screen to provide acceptable speed. A translation of the program to run on another computer would have to include a rewrite of the user interface to adapt it to the new computer.

Error handling

The program recognizes disk file I/O errors and allows you to recover from them without crashing the program. If you attempt to read a file that does not exist, the program will inform you that the file does not exist and ask you to reenter the file name. Most other disk I/O errors are trapped by returning you to one of the program menus.

Mathematical errors are not trapped in the current version of the program. The program is written to check for and avoid many common mathematical errors such as divide by 0, and log of 0 or a negative number. However, on occasion a mathematical error may occur and cause the system to crash. In most cases the QuickBasic error handler will return you to DOS.

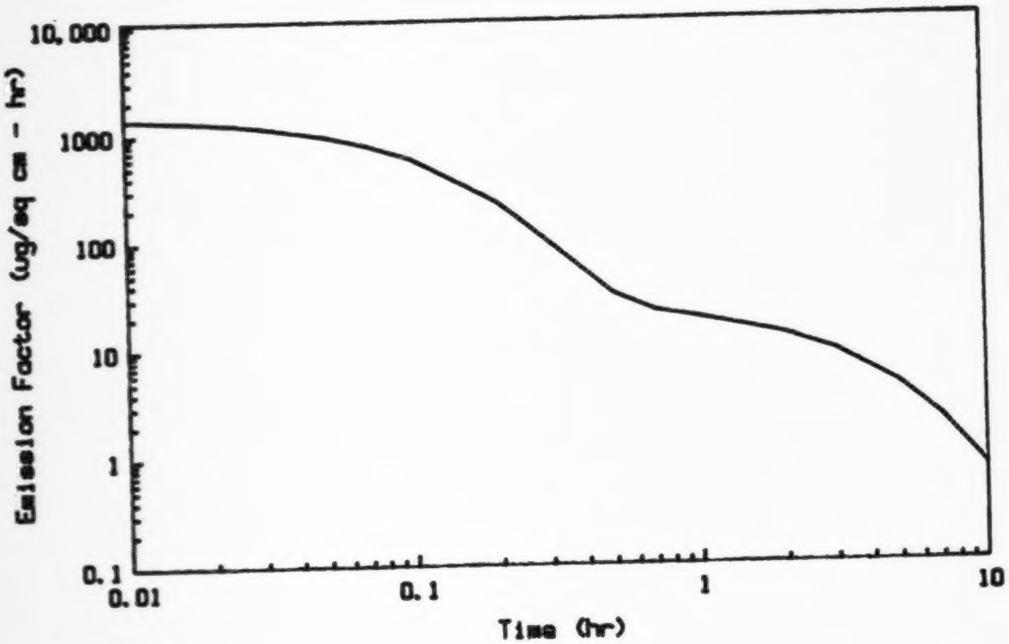


Figure 2-2. Floor wax emission factors, Tichenor et al. (1987)

SECTION 3.
USER GUIDE

Getting Started

The first step in using the model is to read the README.DOC file on the distribution disk. You can do this by typing README from the DOS prompt. The README.DOC file will tell you how to install the program on a hard disk and how to configure the program for your computer.

Note that, if you have a hard disk, the installation program creates a subdirectory called INDOOR. The program and all necessary files are stored in the INDOOR subdirectory.

Once you have installed the program, you can run it by:

a) If you are running from a floppy disk:
   1. Establishing the disk drive with the indoor air program as the active disk drive. (For example if the program disk is in disk drive A, typing A: from the DOS prompt.)
   2. Typing INDOOR to load the program.

b) If you are running from a hard disk:
   1. Establishing the root directory as the active subdirectory by typing cd\ (use uppper or lower case; it doesn't matter).
   2. Typing INDOOR to load the program.

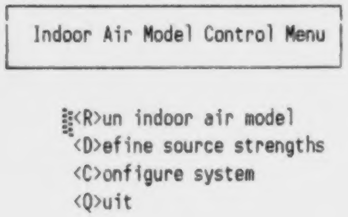
Once the program is loaded, you control program flow by selecting options from the various menus of the program. Each menu and data entry form is discussed below.

The User Interface

The AEERL model provides an easy-to-use interface between the user and the computer. The user interface allows the user to change the input parameters quickly and easily, and rapid analysis of the calculated results.

In a menu-driven interface, you control the flow of the program by selecting options from a menu. The menu options may transfer control to a data entry form, to a sub-menu (indicated by trailing ... on the main menu), or to a program execution portion of the program.

Program operation is controlled by the master menu shown in Figure 3-1. The active menu option is indicated by a highlight bar (shown as ▒ in the figure). The highlight bar is moved up and down the menu by the cursor control keys. When the highlight bar is over the option you wish to execute, press <ENTER> to transfer control to the selected option. You may also transfer control by pressing the letter in <>. Each master control option is discussed below.



Indoor Air Model Control Menu

<R>un indoor air model
<D>efine source strengths
<C>onfigure system
<Q>uit

Figure 3-1. Master control menu.

The first menu option is Run indoor air model. This option transfers control to the indoor air model. It is the most used option in the master menu.

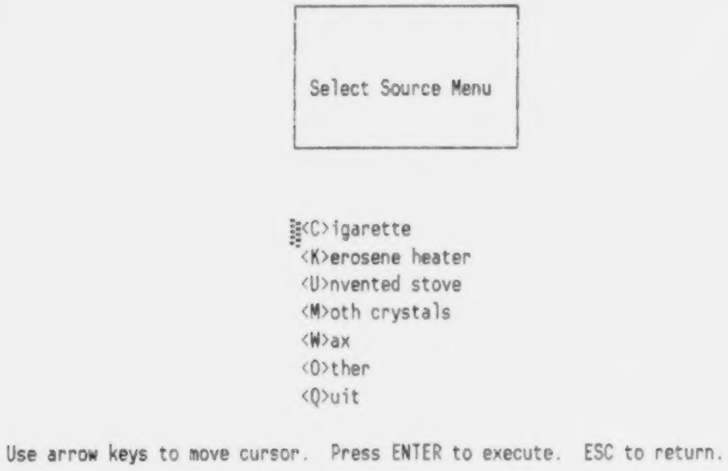
The second option is Define source strengths. This option is used to define sources used as defaults for the model calculations. Note that the default source strengths used in this option can be overwritten during data entry for the model.

The third option is Configure system. This option is used to tell the program what hardware you are using to run the program. Normally you need to run this option only once.

Define source strengths menus and forms

When Define source strengths is selected, program control is passed to the Define source strengths portion of the model. This portion of the model allows you to enter new default emission factors for a wide range of sources.

Program control in this portion of the model is governed by the Select Source menu shown in Figure 3-2.



Select Source Menu

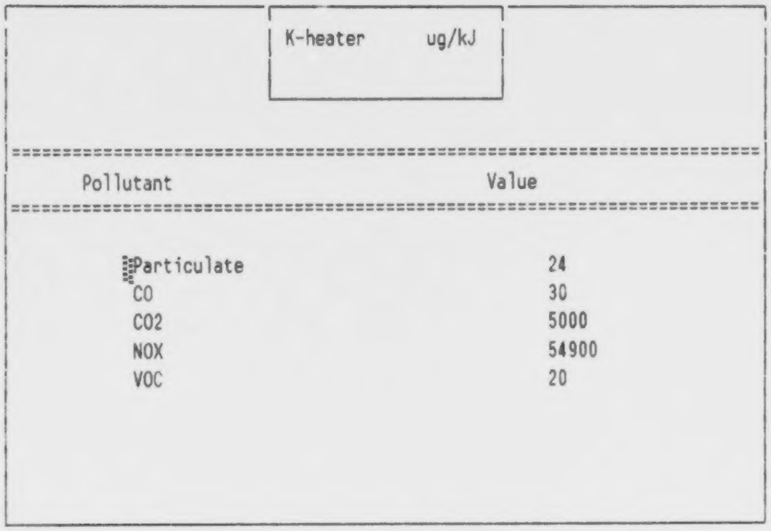
<C>igarette
<K>erosene heater
<U>nvented stove
<M>oth crystals
<W>ax
<O>ther
<Q>uit

Use arrow keys to move cursor. Press ENTER to execute. ESC to return.

Figure 3-2. Select source menu.

The sources shown in Figure 3-2 are those currently supported by the model. When you select a source from the menu, you are transferred to an emission factor data entry form such as shown in Figure 3-3.

Emission factors are entered for each of the pollutants shown. Note that some sources do not emit all pollutants. For example, moth crystals are sources of VOCs but not particulate. In these cases the appropriate emission factor is 0.

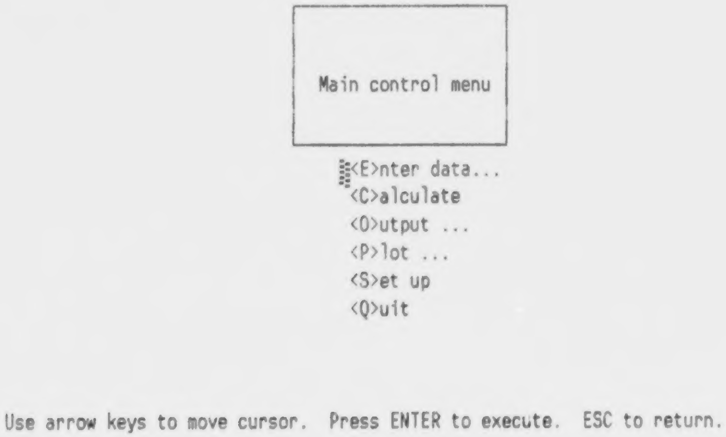


```
K-heater      ug/kJ

=========================================================================
      Pollutant                                Value
=========================================================================

           Particulate                             24
           CO                                      30
           CO2                                     5000
           NOX                                     54900
           VOC                                     20
```

Figure 3-3. Source strength data entry form.

Indoor air model menus and forms

When Run indoor air model is selected from the master menu, control is passed to the main indoor air model menu. This menu controls the operation of the indoor air model and is shown in Figure 3-4.



```
Main control menu

<E>nter data...
<C>alculate
<O>utput ...
<P>lot ...
<S>et up
<Q>uit

Use arrow keys to move cursor.  Press ENTER to execute.  ESC to return.
```

Figure 3-4. Main menu for indoor air model

The first item on the main menu is Enter data. This option transfers control to the data entry menu. The data entry menu is shown in Figure 3-5.

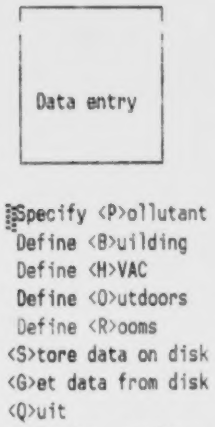
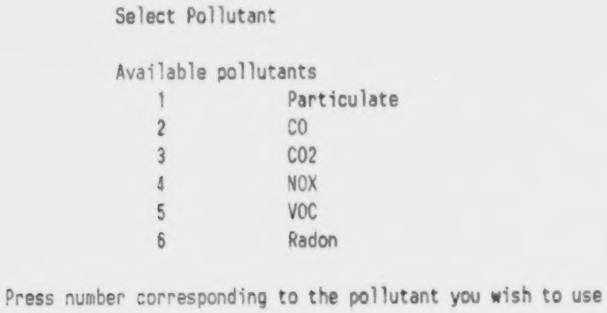

Data entry
Specify <P>ollutant
Define <B>uilding
Define <H>VAC
Define <O>utdoors
Define <R>ooms
<S>tore data on disk
<G>et data from disk
<Q>uit

Figure 3-5. Data entry menu.

The first option is Specify Pollutant. This option allows you to specify the pollutant that is being modeled. When you press P, you are transferred to the pollutant menu shown in Figure 3-6.

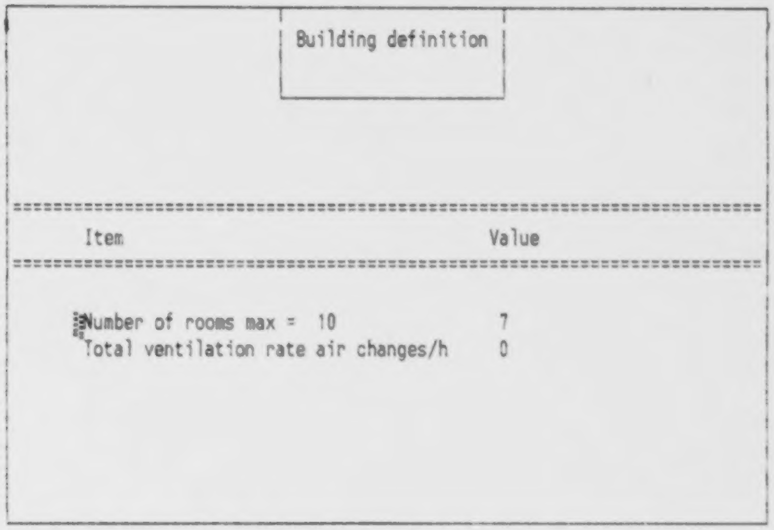


```
        Select Pollutant

        Available pollutants
             1           Particulate
             2           CO
             3           CO2
             4           NOX
             5           VOC
             6           Radon

Press number corresponding to the pollutant you wish to use
```

Figure 3-6. Pollutant menu.

The six pollutants listed are some of the most common indoor air pollutants. Source data for each pollutant, except radon, are provided in the default data files.

The next option is Define Building. When you select this option, the data entry form shown in Figure 3-7 is loaded.



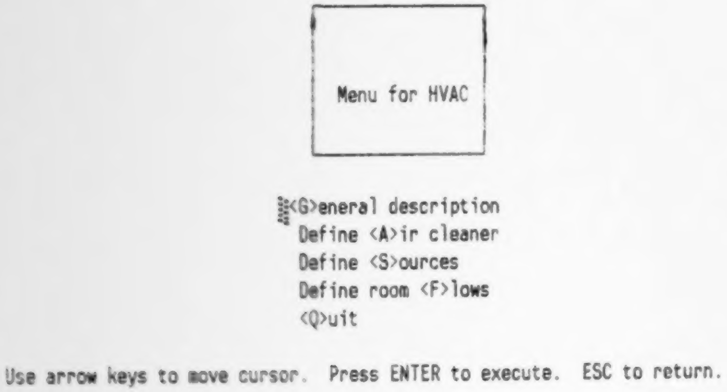
```
                    Building definition

==========================================================================
     Item                                       Value
==========================================================================

     Number of rooms max =  10                   7
     Total ventilation rate air changes/h        0
```

Figure 3-7. Building definition form.

This form is used to enter the number of rooms in the building and the total ventilation rate.

The total ventilation rate is the air exchange between the entire building and the outdoors. The normal units are air changes per hour. The computer evenly distributes the air flow you specify here between rooms based on the volume of the rooms. You can modify this air flow distribution later if you desire.

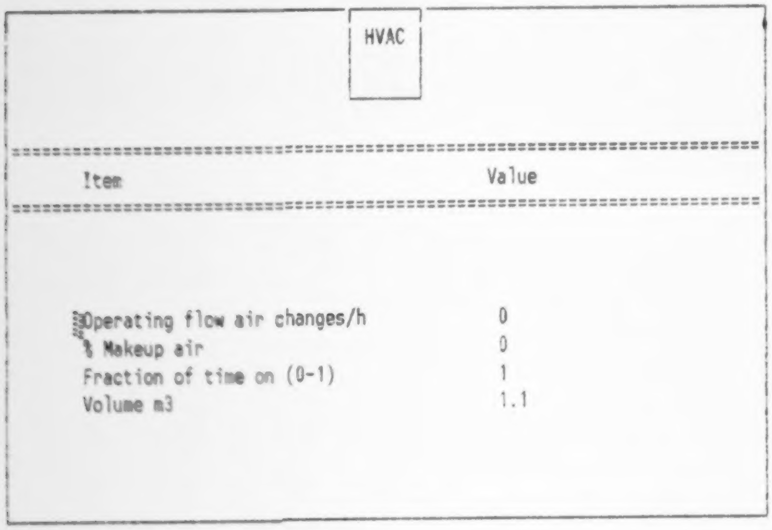
The HVAC option is used to enter data related to the air handling or HVAC system. When this option is selected control is passed to the HVAC menu shown in Figure 3-8.



```
Menu for HVAC

<G>eneral description
Define <A>ir cleaner
Define <S>ources
Define room <F>lows
<Q>uit

Use arrow keys to move cursor.  Press ENTER to execute.  ESC to return.
```

Figure 3-8. HVAC Menu.

General Description is used to enter general information about the HVAC system. When this option is selected, control is passed to the General Description data entry form, Figure 3-9.



```
HVAC

Item                                   Value

Operating flow air changes/h           0
% Makeup air                           0
Fraction of time on (0-1)              1
Volume m3                              1.1
```

Figure 3-9. General description form for HVAC.

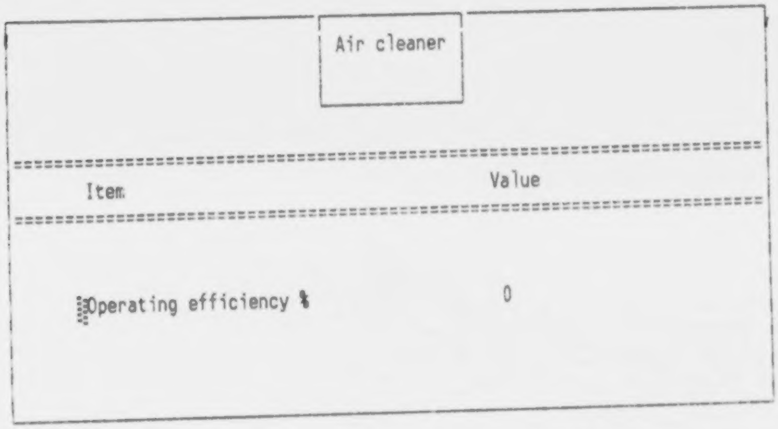
Operating flow air changes/h is the recirculating air flow for the HVAC system. Normal values are between 4 and 7.

% Makeup air is the amount of outdoors air entering the HVAC system. This amount of air replaces a like amount of building air.

Fraction of time on is a fraction used to indicate the fraction of the time that the HVAC system is on. In a commercial building this is normally 1. In a residence this is some fraction less than 1. Fraction of time on determines how often the HVAC system is on.

Volume is the volume of the HVAC system.

The model allows the HVAC to contain an air cleaner. The air cleaner performance is specified by selecting the Define Air Cleaner option from the HVAC menu. The air cleaner data entry form is shown in Figure 3-10. The current version of the model assumes that the air cleaner performance can be described by a single efficiency. Later versions of the model will relax this constraint.

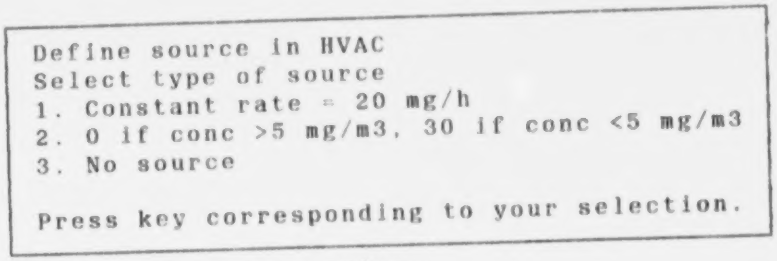


Air cleaner

Item	Value
Operating efficiency %	0

Figure 3-10. Air cleaner data entry form.

The model allows the HVAC to include a source of pollution. You specify the source by selecting the Define Sources option from the HVAC menu. The present version of the model restricts the HVAC pollution sources to those shown in Figure 3-11.



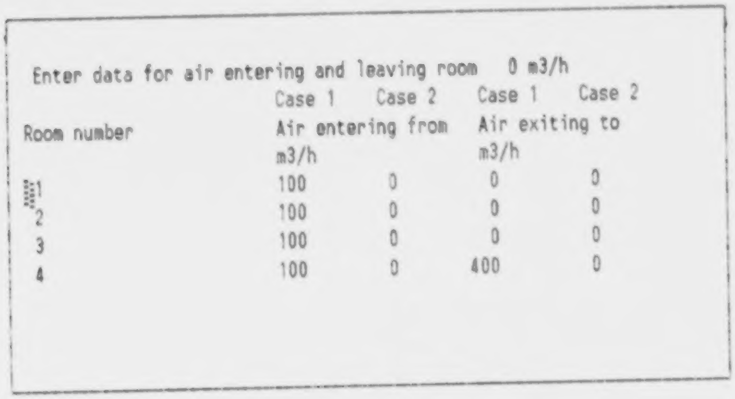
```
Define source in HVAC
Select type of source
1. Constant rate = 20 mg/h
2. 0 if conc >5 mg/m3, 30 if conc <5 mg/m3
3. No source

Press key corresponding to your selection.
```

Figure 3-11. HVAC source data entry.

The air flows between the various rooms and the HVAC system can be specified either by filling in the form for the HVAC system, or by filling in a form for each room. The HVAC flow form is selected by selecting the Define Room Flows option from the HVAC menu. When this option is selected, control is passed to the HVAC room flow data entry form, Figure 3-12. Note that flows may be specified for two cases: in Case 1, the HVAC is on as determined by the fraction of time on; and in Case 2, the HVAC is off as determined by the fraction of time off. The flows entered here can be adjusted when air flows for individual rooms are specified.

Normally the two air flow cases will be used to describe flows when the HVAC in on or off. In this case the flows for Case 2 (HVAC off) will be zero. The example shows a four room house with HVAC providing 100 m^2/h to each room. The HVAC return is in Room 4 and is 400 m^3/h. The Case 2 flows are all zero.

The two air flow patterns can also be used to simulate other situations where the air flow patterns could be changed periodically; e.g., opening and closing a door between rooms.

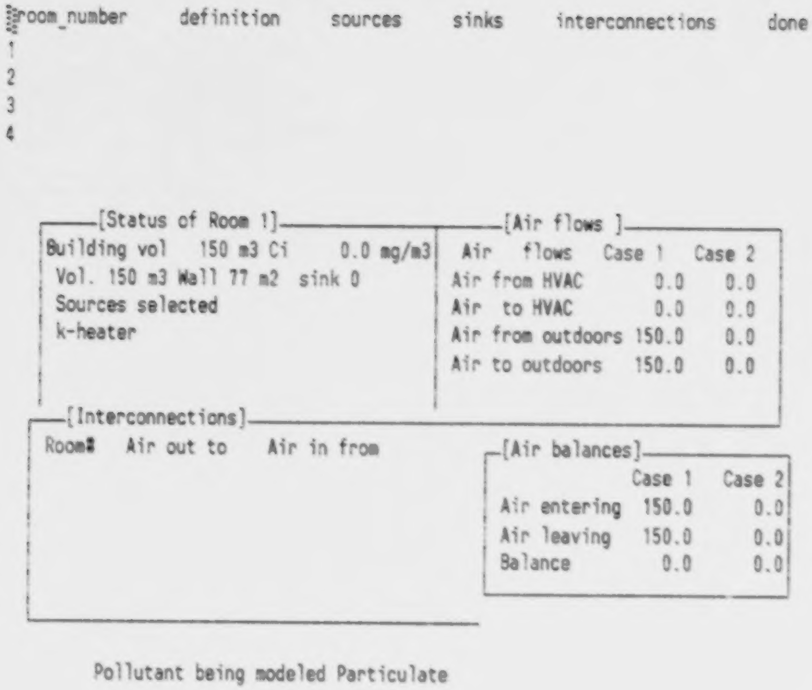


Enter data for air entering and leaving room 0 m3/h

Room number	Case 1 Air entering from m3/h	Case 2	Case 1 Air exiting to m3/h	Case 2
1	100	0	0	0
2	100	0	0	0
3	100	0	0	0
4	100	0	400	0

Figure 3-12. HVAC air flow data entry form.

The most complicated menu option is Define Room. This option is used to define the size, sources, sinks, and air flows in individual rooms. When this option is selected, control is passed to the room definition screen. This screen is a Lotus type screen shown in Figure 3-13.



```
room_number     definition     sources     sinks     interconnections     done
1
2
3
4

  ——[Status of Room 1]————————————————————————[Air flows ]——————————
 |Building vol   150 m3 Ci      0.0 mg/m3| Air    flows   Case 1   Case 2 |
 | Vol. 150 m3 Wall 77 m2  sink 0        |Air from HVAC        0.0     0.0 |
 | Sources selected                      |Air  to HVAC         0.0     0.0 |
 | k-heater                              |Air from outdoors  150.0     0.0 |
 |                                       |Air to outdoors    150.0     0.0 |
 |                                       |                                 |
 ——[Interconnections]————————————————————————————————————————————————
 Room#   Air out to    Air in from
|                                        ——[Air balances]—————————————
|                                       |               Case 1   Case 2|
|                                       | Air entering   150.0      0.0|
|                                       | Air leaving    150.0      0.0|
|                                       | Balance          0.0      0.0|
|                                        ——————————————————————————————
 ————————————————————————————————————————

      Pollutant being modeled Particulate
```

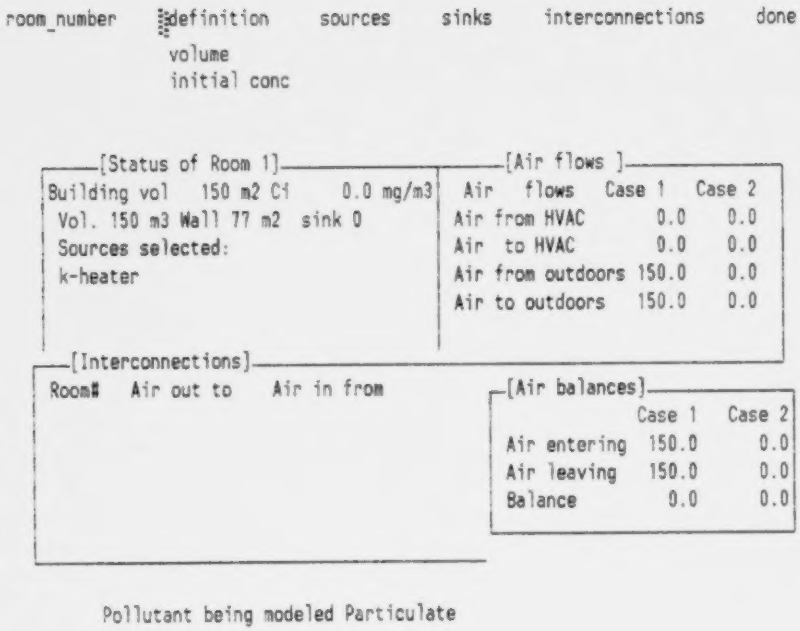
Figure 3-13. Room definition screen.

This figure shows the overall room definition screen. The options available from this screen are:

Select room number
Define room size and initial concentration (definition)
Define sources
Define sinks
Define interconnections with outdoors, HVAC, and other rooms.

The various options are selected by moving the highlight bar across the top of the screen using the left and right arrow keys. When the highlight bar is over an option, all the choices available under that option are displayed. For example, the highlight bar is over room number in Figure 3-13 and the available room numbers are displayed. Choices are selected by moving the highlight bar up and down with the up and down arrow keys. When the highlight bar is over the desired choice, press ENTER to activate the desired option.

For example to work with Room 1, move the highlight bar over 1 and press ENTER. To define the volume and initial concentration of Room 1, move the highlight bar to definition. The screen display is changed to Figure 3-14.

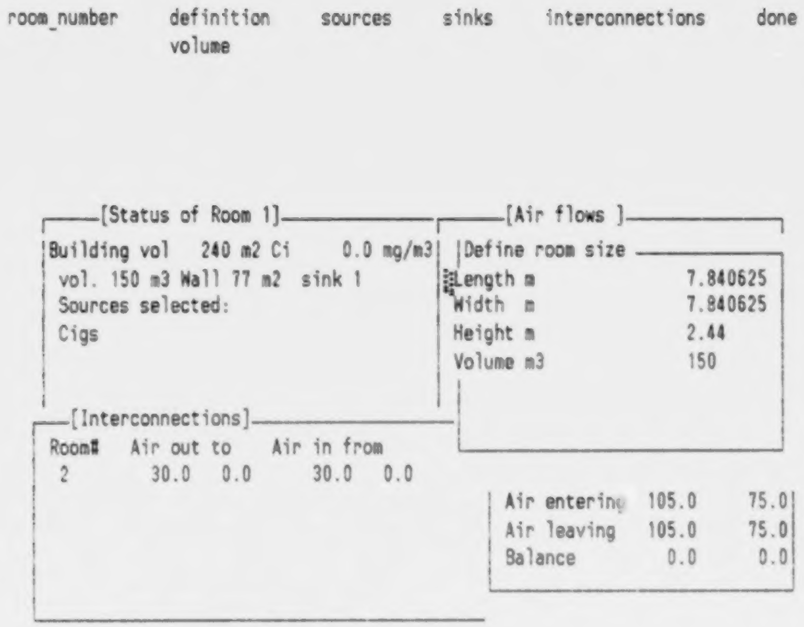


```
room_number   definition    sources    sinks    interconnections    done
              volume
              initial conc

  ______[Status of Room 1]______________________________[Air flows ]___________
 |Building vol   150 m2 Ci      0.0 mg/m3|  Air    flows    Case 1    Case 2  |
 | Vol. 150 m3 Wall 77 m2  sink 0         | Air from HVAC        0.0      0.0  |
 | Sources selected:                      | Air  to HVAC         0.0      0.0  |
 | k-heater                               | Air from outdoors 150.0      0.0  |
 |                                        | Air to outdoors   150.0      0.0  |
 |                                        |                                   |
 __[Interconnections]___________________________________________________________
| Room#   Air out to    Air in from      __[Air balances]_________________
|                                        |              Case 1    Case 2 |
|                                        | Air entering  150.0       0.0 |
|                                        | Air leaving   150.0       0.0 |
|                                        | Balance         0.0       0.0 |
|                                        |_______________________________|
|______________________________________________

      Pollutant being modeled Particulate
```

Figure 3-14. Room screen showing definition options.

Room volume is selected by moving the highlight bar down to volume and pressing ENTER. The screen changes to Figure 3-15. Note that a data entry window containing the room size form opens in the middle right portion of the screen. This data entry form operates the same as every other data entry from in the program. Move up and down the form by pressing the up and down arrows. When all the data are entered, press ESC to return to the room definition form.

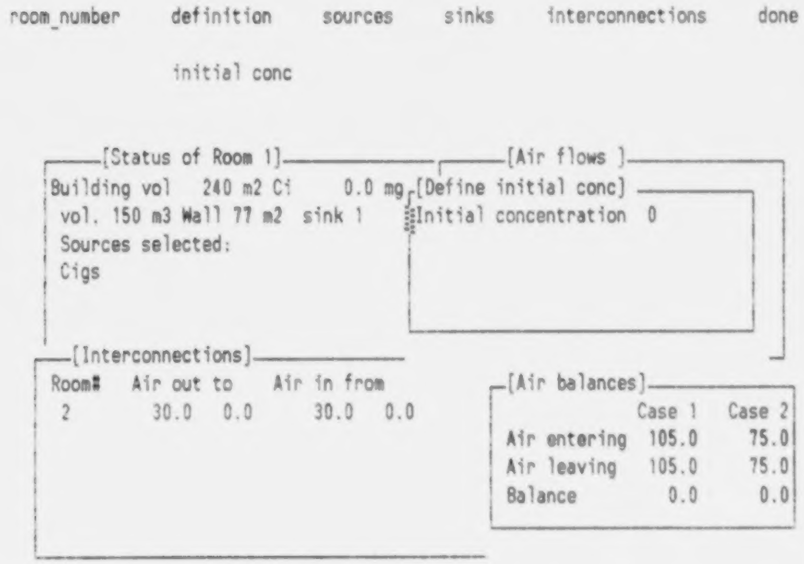
If a volume for the room is entered, the program assumes that the room is square with 2.44 m high walls.



```
room_number     definition     sources     sinks     interconnections     done
                volume



  ┌────[Status of Room 1]─────────────┌─────────[Air flows ]─────────┐
  │Building vol   240 m2 Ci     0.0 mg/m3│ │Define room size ─────────────┐
  │ vol. 150 m3 Wall 77 m2  sink 1    │Length m              7.840625 │
  │ Sources selected:                 │ Width  m              7.840625 │
  │ Cigs                              │ Height m              2.44     │
  │                                   │ Volume m3             150      │
  │                                   │ │                              │
 ──[Interconnections]───────────────── │                              │
 │ Room#   Air out to     Air in from    └──────────────────────────────┘
 │  2        30.0   0.0      30.0   0.0
 │                                       │ Air entering  105.0     75.0│
 │                                       │ Air leaving   105.0     75.0│
 │                                       │ Balance         0.0      0.0│
 │                                       └─────────────────────────────┘
 └────────────────────────────────────
```

Figure 3-15. Room screen ready to define size of room.

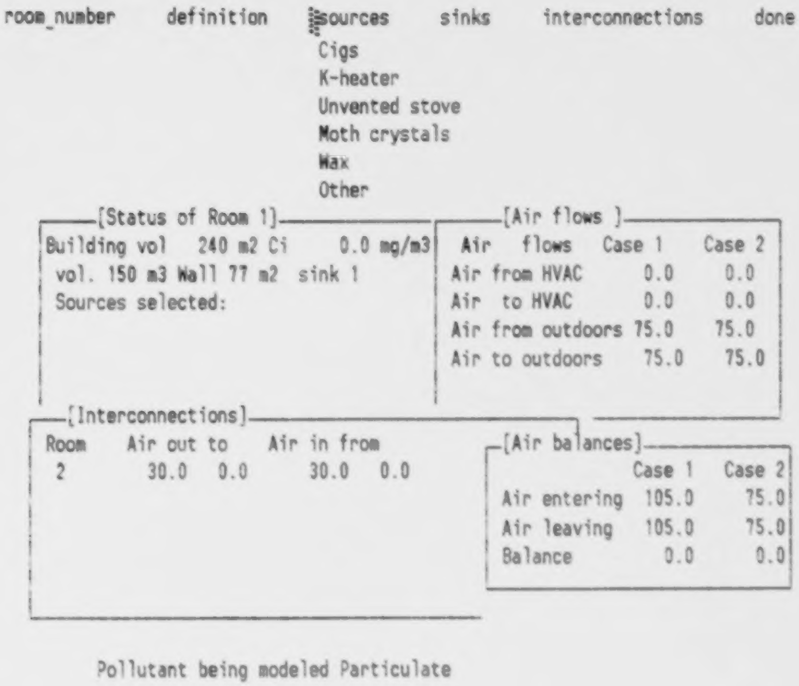
The initial pollutant concentration in a room can be specified by selecting the initial conc option and pressing ENTER. This gives Figure 3-16. Note that the initial concentration data entry form now appears in the data entry window after Ci.



```
room_number     definition     sources     sinks     interconnections     done

                initial conc



  ┌────[Status of Room 1]──────────────┌──────[Air flows ]──────────┐
  │Building vol   240 m2 Ci     0.0 mg┌[Define initial conc] ──────┐ │
  │ vol. 150 m3 Wall 77 m2  sink 1    │Initial concentration  0    │ │
  │ Sources selected:                 │                            │ │
  │ Cigs                              │                            │ │
  │                                   │                            │ │
  │                                   └────────────────────────────┘ │
 ──[Interconnections]─────────────                                  ─┘
 │ Room#   Air out to     Air in from        ┌[Air balances]─────────────┐
 │  2        30.0   0.0      30.0   0.0      │              Case 1  Case 2│
 │                                           │ Air entering  105.0    75.0│
 │                                           │ Air leaving   105.0    75.0│
 │                                           │ Balance         0.0     0.0│
 │                                           └────────────────────────────┘
 └────────────────────────────────────
```

Figure 3-16. Room screen ready to define initial concentration.

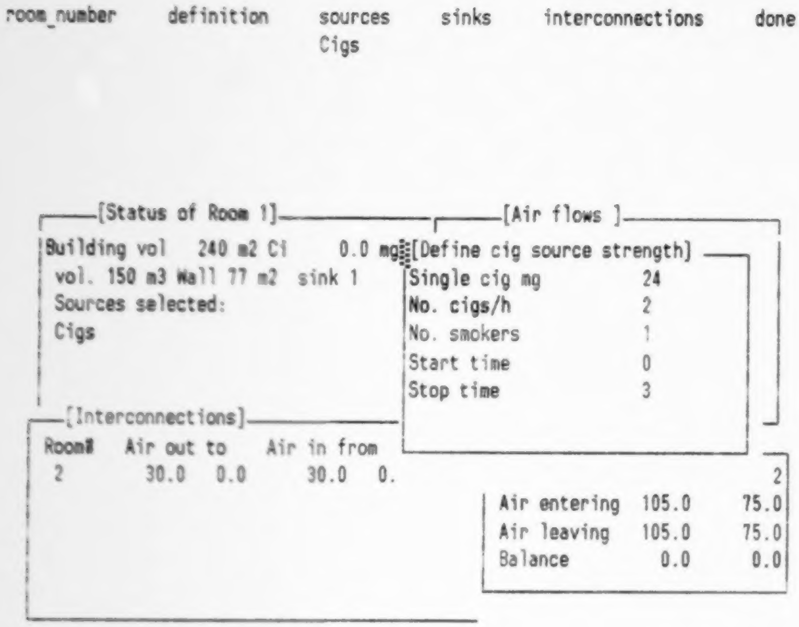
The next set of options is select sources. The screen for select sources is shown in Figure 3-17.



```
room_number    definition    sources    sinks    interconnections    done
                             Cigs
                             K-heater
                             Unvented stove
                             Moth crystals
                             Wax
                             Other
 ───[Status of Room 1]──────────── ───────[Air flows ]──────────
|Building vol   240 m2 Ci    0.0 mg/m3|  Air   flows   Case 1    Case 2 |
| vol. 150 m3 Wall 77 m2  sink 1      | Air from HVAC      0.0      0.0 |
| Sources selected:                   | Air  to HVAC       0.0      0.0 |
|                                     | Air from outdoors 75.0     75.0 |
|                                     | Air to outdoors    75.0    75.0 |
|                                     |                                  |
 ──[Interconnections]──────────────────────┐    ───────────────
| Room    Air out to     Air in from       ─[Air balances]──────────
|  2        30.0   0.0      30.0   0.0     |              Case 1   Case 2|
|                                          | Air entering  105.0     75.0|
|                                          | Air leaving   105.0     75.0|
|                                          | Balance         0.0      0.0|
|                                           ─────────────────────────────
 ──────────────────────────────────────

      Pollutant being modeled Particulate
```

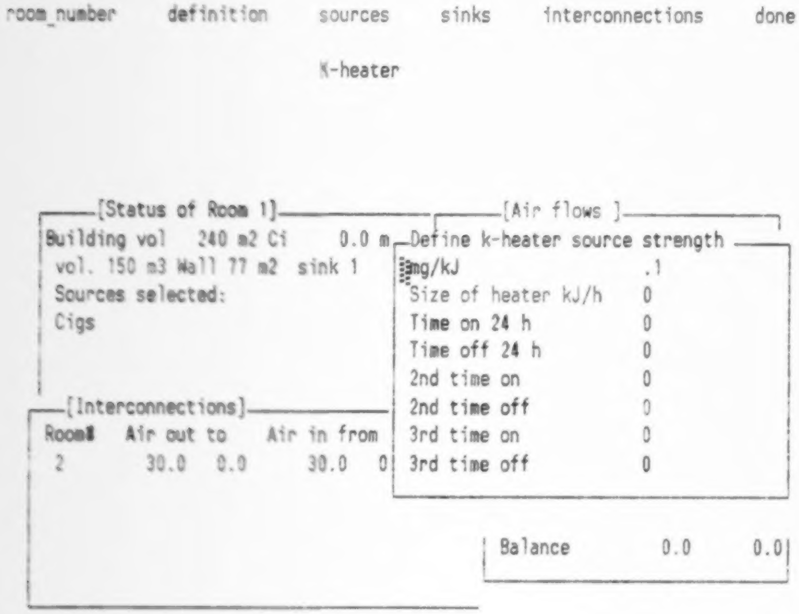
Figure 3-17. Room screen showing source options.

When a source is selected, the data entry form for that source is displayed in the data entry window. Data entry screens for all sources are shown in Figures 3-18 through 3-23.



```
room_number     definition     sources     sinks     interconnections     done
                               Cigs


[Status of Room 1]                              [Air flows ]
Building vol   240 m2 Ci     0.0 mg[Define cig source strength]
 vol. 150 m3 Wall 77 m2  sink 1    Single cig mg          24
 Sources selected:                 No. cigs/h             2
 Cigs                              No. smokers            1
                                   Start time             0
                                   Stop time              3
[Interconnections]
 Room#   Air out to    Air in from
  2        30.0   0.0      30.0   0.                                     2
                                       Air entering  105.0       75.0
                                       Air leaving   105.0       75.0
                                       Balance         0.0        0.0
```

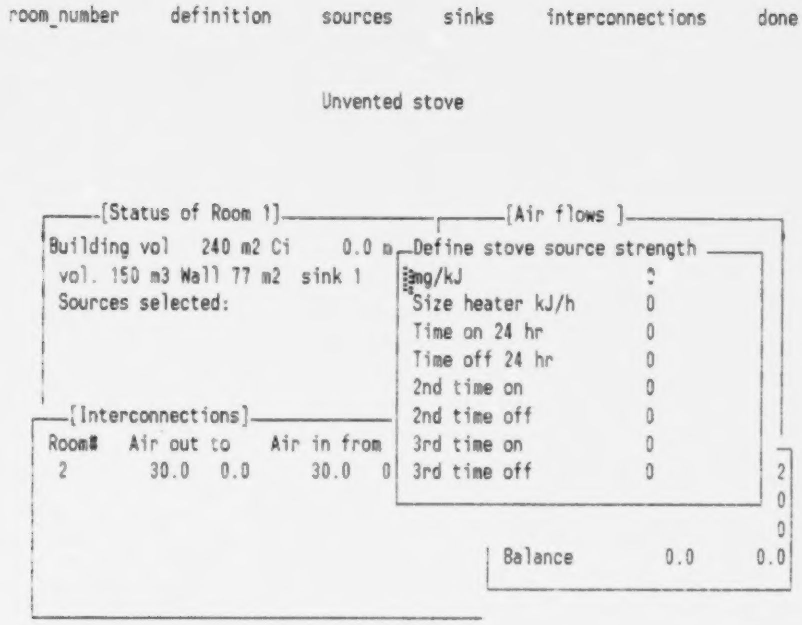
Figure 3-18. Room screen showing cigarette data entry.



```
room_number     definition     sources     sinks     interconnections     done

                               K-heater


[Status of Room 1]                              [Air flows ]
Building vol   240 m2 Ci     0.0 m Define k-heater source strength
 vol. 150 m3 Wall 77 m2  sink 1    mg/kJ                  .1
 Sources selected:                 Size of heater kJ/h    0
 Cigs                              Time on 24 h           0
                                   Time off 24 h          0
                                   2nd time on            0
[Interconnections]                 2nd time off           0
 Room#   Air out to    Air in from 3rd time on            0
  2        30.0   0.0      30.0   0 3rd time off          0


                                       Balance         0.0        0.0
```

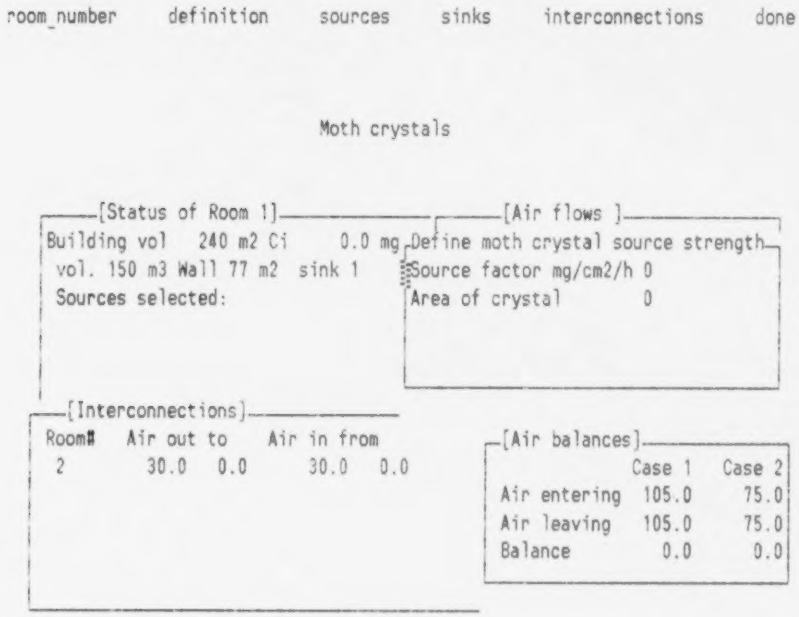
Figure 3-19. Room screen showing kerosene heater data entry.

(The text "Balance 0.0 0.0" shown above and similar text in later figures is from the main screen that is overlayed by the data entry window.)



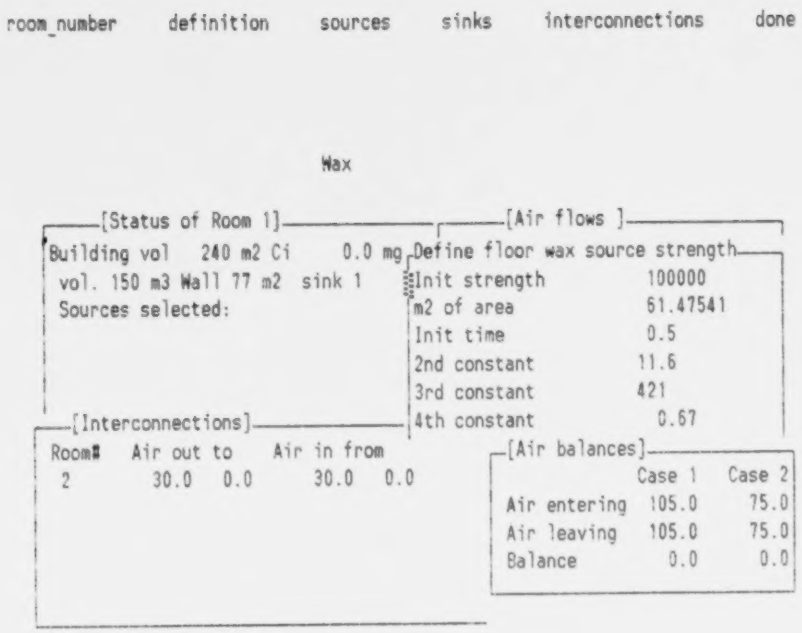
```
room_number    definition    sources    sinks    interconnections    done

                              Unvented stove

-[Status of Room 1]--------------------   -[Air flows ]---------------
Building vol   240 m2 Ci     0.0 m -Define stove source strength -
 vol. 150 m3 Wall 77 m2  sink 1    mg/kJ                   0
 Sources selected:                  Size heater kJ/h        0
                                    Time on 24 hr           0
                                    Time off 24 hr          0
                                    2nd time on             0
-[Interconnections]--------------   2nd time off            0
Room#   Air out to     Air in from  3rd time on             0
 2         30.0   0.0      30.0   0 3rd time off            0         2
                                                                      0
                                                                      0
                                        Balance         0.0       0.0
```

Figure 3-20. Room screen showing unvented stove data entry.



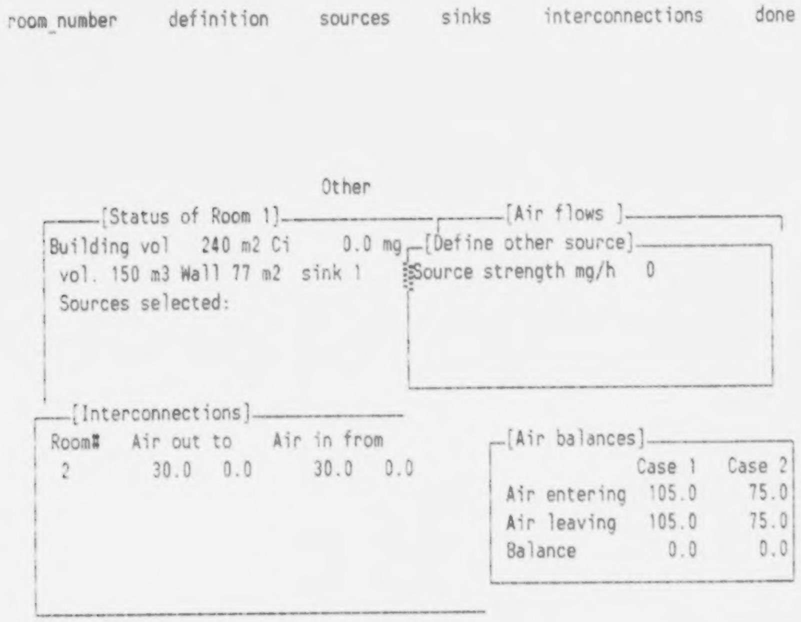
```
room_number    definition    sources    sinks    interconnections    done

                              Moth crystals

-[Status of Room 1]--------------------  -[Air flows ]----------------
Building vol   240 m2 Ci     0.0 mg-Define moth crystal source strength-
 vol. 150 m3 Wall 77 m2  sink 1    Source factor mg/cm2/h 0
 Sources selected:                 Area of crystal        0

-[Interconnections]--------------
Room#   Air out to     Air in from         -[Air balances]-----------
 2         30.0   0.0      30.0   0.0                    Case 1   Case 2
                                           Air entering   105.0     75.0
                                           Air leaving    105.0     75.0
                                           Balance          0.0      0.0
```

Figure 3-21. Room screen showing moth crystal data entry.



```
room_number     definition     sources     sinks     interconnections     done



                            Wax

 -----[Status of Room 1]----------- ------[Air flows ]----------------
|Building vol   240 m2 Ci     0.0 mg|Define floor wax source strength---
|  vol. 150 m3 Wall 77 m2  sink 1   |Init strength           100000     |
|  Sources selected:                |m2 of area              61.47541   |
|                                   |Init time               0.5        |
|                                   |2nd constant           11.6        |
|                                   |3rd constant           421         |
 ---[Interconnections]--------------|4th constant             0.67      |
| Room#   Air out to    Air in from       --[Air balances]-------------
|  2        30.0   0.0      30.0   0.0    |              Case 1  Case 2|
|                                         |Air entering   105.0    75.0|
|                                         |Air leaving    105.0    75.0|
|                                         |Balance          0.0     0.0|
|                                          ----------------------------
 -----------------------------------------
```

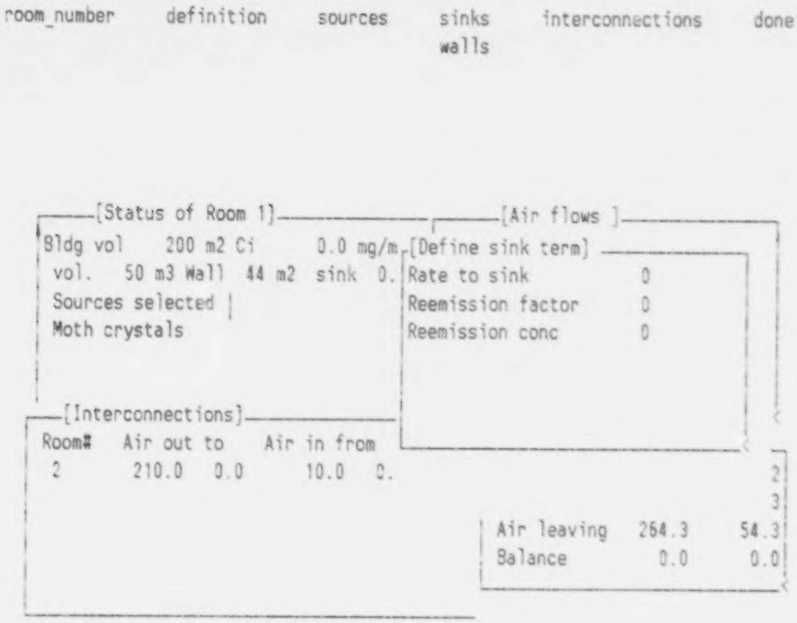
Figure 3-22. Floor wax data entry screen.



```
room_number     definition     sources     sinks     interconnections     done



                              Other

 -----[Status of Room 1]----------- ------[Air flows ]----------------
|Building vol   240 m2 Ci     0.0 mg--[Define other source]--------
|  vol. 150 m3 Wall 77 m2  sink 1   |Source strength mg/h   0     |
|  Sources selected:                |                             |
|                                   |                             |
|                                    ------------------------------
 ---[Interconnections]-------------
| Room#   Air out to    Air in from       --[Air balances]-------------
|  2        30.0   0.0      30.0   0.0    |              Case 1  Case 2|
|                                         |Air entering   105.0    75.0|
|                                         |Air leaving    105.0    75.0|
|                                         |Balance          0.0     0.0|
|                                          ----------------------------
 -----------------------------------------
```

Figure 3-23. Room screen showing other source data entry.

The next option is the sink description option, shown in Figure 3-24.



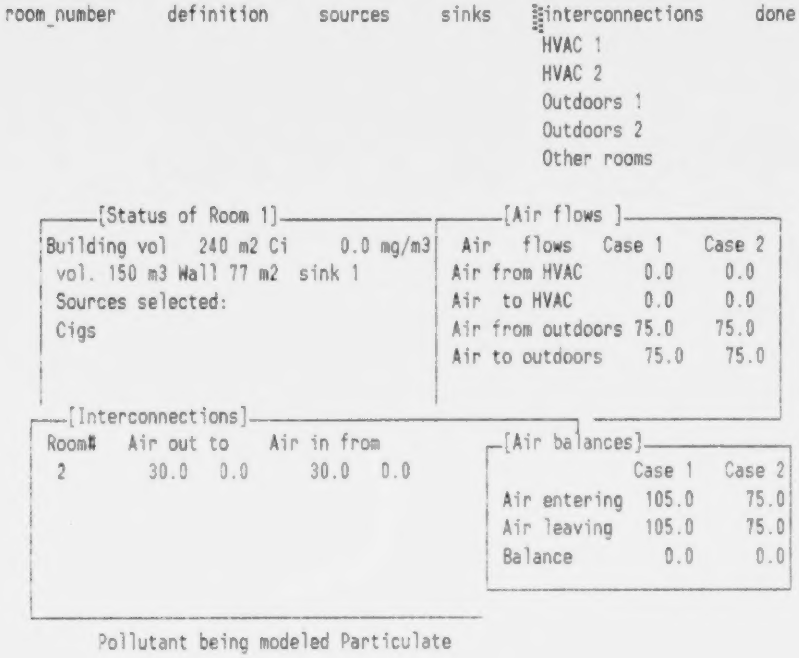
```
room_number     definition     sources     sinks     interconnections     done
                                           walls
```

```
┌─────[Status of Room 1]──────────────┌───────[Air flows ]──────────────┐
|Bldg vol    200 m2 Ci       0.0 mg/m┌[Define sink term] ──────────┐  |
| vol.   50 m3 Wall  44 m2  sink  0. |Rate to sink             0   |  |
| Sources selected |                 |Reemission factor        0   |  |
| Moth crystals                      |Reemission conc          0   |  |
|                                    |                             |  |
|                                    |                             |  <
──[Interconnections]─────────        |                             |
|Room#   Air out to     Air in from  └─────────────────────────────<  ┐
| 2       210.0   0.0       10.0   0.                                2|
|                                                                    3|
|                                      | Air leaving   264.3     54.3|
|                                      | Balance         0.0      0.0|
|                                      └─────────────────────────────<
└──────────────────────────────────────
```

Figure 3-24. Room screen showing sink data entry.

Data for the sink are entered using the form shown in Figure 3-24. A sink is described by three terms--the rate to the sink, the concentration at which reemission begins, and a reemission constant. There are few data on sinks, and reasonable values of the sink terms are difficult to estimate. Limited experimental data from the EPA test house indicate that the rate to the sink for many volatile organic compounds (VOCs) is between 0.16 and 0.35 m/h. Reasonable values for the reemission concentrations are between 30 and 1000 $\mu g/m^3$. And reasonable values of the sink reemission factor are between 5 and 50. The rate to the sink and the sink reemission factor have units of concentration per hour per unit area.

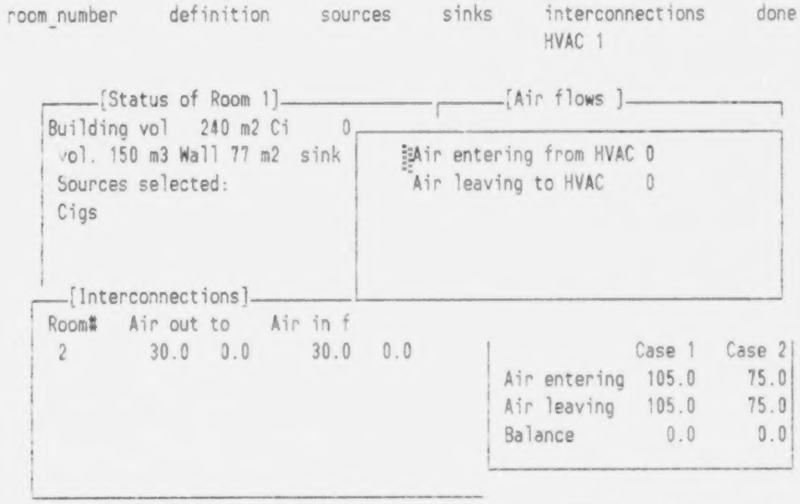
The final option is the interconnections option. This option is used to define the air flows entering and leaving the room. The interconnections screen is shown in Figure 3-25.



```
room_number     definition     sources     sinks     interconnections     done
                                                      HVAC 1
                                                      HVAC 2
                                                      Outdoors 1
                                                      Outdoors 2
                                                      Other rooms

  ┌──────[Status of Room 1]────────────┬───────[Air flows ]──────────┐
  │Building vol   240 m2 Ci      0.0 mg/m3│ Air    flows   Case 1   Case 2│
  │ vol. 150 m3 Wall 77 m2  sink 1      │Air from HVAC      0.0      0.0 │
  │ Sources selected:                  │Air  to HVAC       0.0      0.0 │
  │ Cigs                               │Air from outdoors 75.0     75.0 │
  │                                    │Air to outdoors    75.0     75.0 │
  │                                    │                               │
 ┌──[Interconnections]──────────────────────┐                           │
 │ Room#   Air out to     Air in from       ┌─[Air balances]───────────┐
 │  2        30.0   0.0      30.0   0.0    │             Case 1   Case 2│
 │                                        │ Air entering  105.0     75.0│
 │                                        │ Air leaving   105.0     75.0│
 │                                        │ Balance         0.0      0.0│
 │                                        └──────────────────────────┘
 └────────────────────────────────────────┘
         Pollutant being modeled Particulate
```

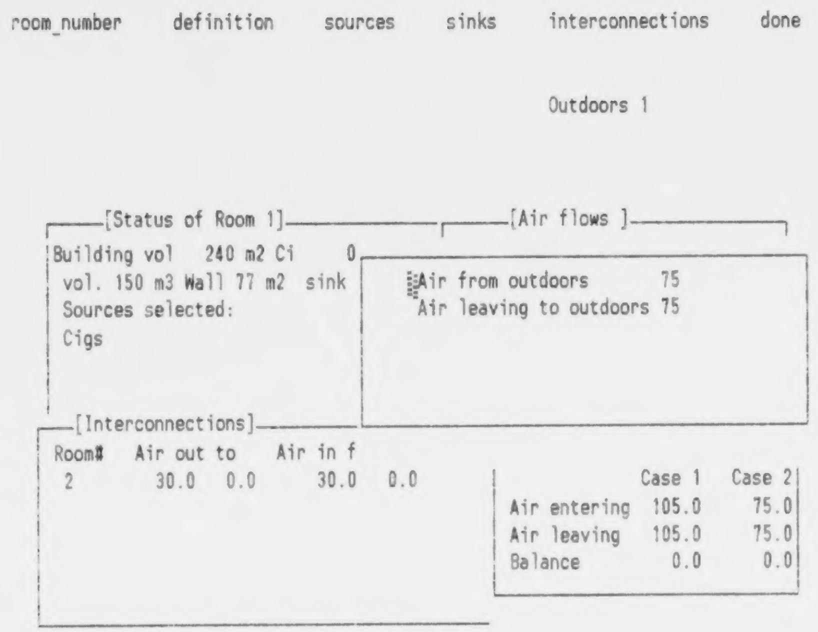
Figure 3-25. Room screen showing interconnections option.

The interconnections options HVAC 1, HVAC 2, Outdoors 1, and Outdoors 2 transfer control to a data entry form in the data entry window. The screens for these options are shown in Figures 3-26 through 3-28.



```
room_number     definition     sources     sinks     interconnections     done
                                                      HVAC 1

  ┌──────[Status of Room 1]────────────┬───────[Air flows ]──────────┐
  │Building vol   240 m2 Ci      0 ┌─────────────────────────────────┐
  │ vol. 150 m3 Wall 77 m2  sink   │    Air entering from HVAC 0       │
  │ Sources selected:              │    Air leaving to HVAC    0       │
  │ Cigs                           │                                 │
  │                                │                                 │
 ┌──[Interconnections]─────────────└─────────────────────────────────┘
 │ Room#   Air out to     Air in f
 │  2        30.0   0.0      30.0   0.0    │             Case 1   Case 2│
 │                                        │ Air entering  105.0     75.0│
 │                                        │ Air leaving   105.0     75.0│
 │                                        │ Balance         0.0      0.0│
 │                                        └──────────────────────────┘
 └────────────────────────────────────────┘
```

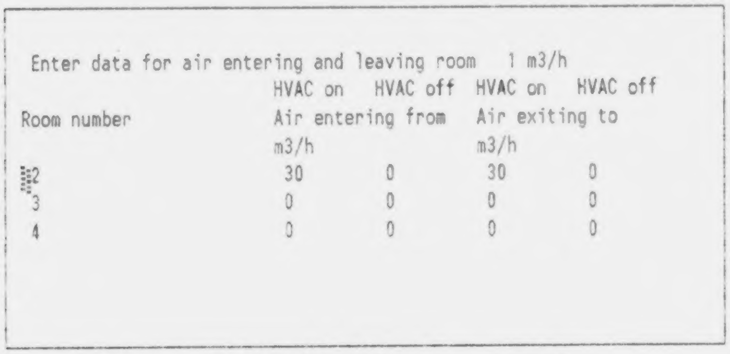
Figure 3-26. Room screen showing HVAC flow data entry.



```
room_number     definition     sources     sinks     interconnections     done

                                                Outdoors 1


 ┌──────[Status of Room 1]──────────────┌─────────[Air flows ]──────────┐
 |Building vol   240 m2 Ci      0──────────────────────────────────────┐
 | vol. 150 m3 Wall 77 m2  sink  |   Air from outdoors        75      |
 | Sources selected:             |   Air leaving to outdoors  75      |
 | Cigs                          |                                    |
 |                               |                                    |
 |                               |                                    |
 ───[Interconnections]───────────└────────────────────────────────────┘
 |Room#   Air out to     Air in f
 |  2        30.0   0.0      30.0   0.0    |            Case 1   Case 2|
 |                                          | Air entering  105.0     75.0|
 |                                          | Air leaving   105.0     75.0|
 |                                          | Balance         0.0      0.0|
 |                                          └─────────────────────────────┘
 └──────────────────────────────────────────
```

Figure 3-27. Room screen showing outdoor flow data entry.

The data entry form for defining the flows between rooms is a full screen data entry form as shown in Figure 3-28.



```
┌─────────────────────────────────────────────────────────────────────┐
|                                                                     |
| Enter data for air entering and leaving room   1 m3/h               |
|                                 HVAC on   HVAC off  HVAC on   HVAC off
| Room number                     Air entering from   Air exiting to  |
|                                 m3/h                m3/h            |
|  2                               30        0         30        0    |
|  3                               0         0         0         0    |
|  4                               0         0         0         0    |
|                                                                     |
|                                                                     |
└─────────────────────────────────────────────────────────────────────┘
```

Figure 3-28. Room flow data entry form.

Note that the room definition screen shows all the flows and the air flow balance. The air flow balance should be zero after all air flows are defined.

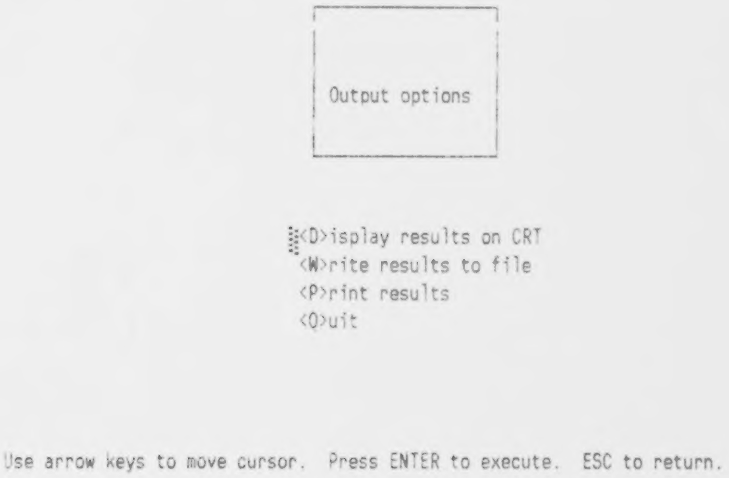
When all data have been entered, the program can be run by pressing R for Run Program from the main menu. As soon as the Run Program instruction is given, the program does a limited check of the consistency of the data you entered. If an inconsistency is found, an error message is presented and you are asked if you want to continue or reenter data. The most common data inconsistency is that the overall ventilation rate specified in the define building form is different from the overall ventilation rate calculated by summing all the individual room ventilation rates. In this case the computer asks if you want to use the sum of the individual rooms as the ventilation rate. The proper response is generally Y.

In general, respond to the error message by pressing Y, except when the error message indicates that the flows do not balance. In this case reenter the data.

While the program is running, a simple bar chart of pollutant concentrations in each room is shown. If a source is on in the room, the concentrations are displayed as +. If there is no source on in the room, concentrations are shown as -. The cumulative emissions, cumulative amount leaving building, cumulative amount in the sink, and the amount currently in the building are also displayed. These allow you to check for conservation of mass. (Note, however, that if the outdoor concentration is greater than zero, you cannot check for conservation.) The calculations can be stopped at any time by pressing the ESC key.

When all calculations have been completed, program control is returned to the main menu.

The program provides several output options. These are selected by pressing O on the main menu. When output is selected, program control is passed to the output options menu, Figure 3-29.



Output options

<D>isplay results on CRT
<W>rite results to file
<P>rint results
<Q>uit

Use arrow keys to move cursor. Press ENTER to execute. ESC to return.

Figure 3-29. Output options menu.

The first output option is Display results on CRT. If you select this option, all the calculated results will be displayed on the CRT, a screen at a time. Advance the display by pressing any key. Return to the output menu at any time, by pressing ESC.

The second output option is Write results to file. If you select this option, you will be asked for a file name. Enter any legal DOS file name with less than six characters and without an extension. The program will use this file name to create a family of files for the calculated results. A file is created for each room. The files all have the extension DAT.

The file name is created by adding the room number and the extension .DAT to the file name you supplied. The HVAC is filed as Room 0. For example, if you have a four room model plus HVAC, the program will create the following files:

TEST0.DAT	for the HVAC system
TEST1.DAT	for Room 1
TEST2.DAT	for Room 2
TEST3.DAT	for Room 3
TEST4.DAT	for Room 4.

The data are written to the file as time concentration pairs.

Data from the files can be recalled from the plot results menu for comparison with other calculations. The data can also be recalled for plotting by a plotting package.

The output of the calculations can be printed on a line printer by selecting Print results.

The most generally useful display of results is provided by a graph of the results. Graphs of the results can be obtained by selecting Plot from the main menu, Figure 3-4. When Plot is selected, control is passed to the Plot menu shown in Figure 3-30.

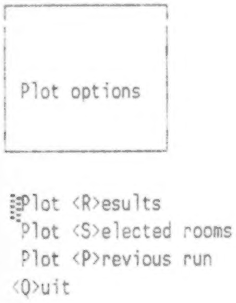


Figure 3-30. Plot menu.

The first plotting option is Plot Results. This option plots all the results of the current calculation. If the program is configured for an EGA card and monitor, all the rooms are plotted at once. The curve for each room is shown as a different color. If the program is configured for a CGA, the rooms are plotted one room at a time. However, all rooms are plotted on the same plot. Graphics are not available for monochrome monitors.

Plot Selected rooms allows you to plot one or more rooms. If you select this option, you will be asked for a list of the rooms you want plotted. Terminate the list with the word 'end.' The advantage of this option is that the graph will be scaled for the results of the room or rooms of interest.

Plot Previous run allows you to recall and plot results from previous calculations. This option allows you to compare results from a number of calculations. When you select this option you are asked for a file name where the previous results are stored. You are then asked which room you want to plot the recalled data as. When you respond to this question, the recalled data replace the data for the indicated room.

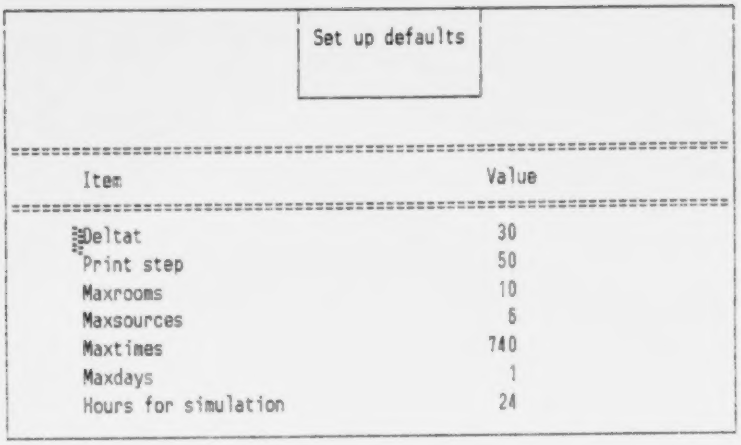
For example, when investigating the impact of ventilation on pollution concentrations, you are only interested in Room 1 of a four room building. Calculation 1 was stored as TESTA, calculation 2 as TESTB, and calculation 3 as TESTC. Calculation 4 has been completed but not stored. You now wish to compare the effects of the various ventilation rates on the pollution concentrations in Room 1.

Select Plot Previous results. Tell the computer you wish to recall TESTA1 (remember that the computer creates the data files by adding the room number to your file name) and you want to plot the data as Room 2. Now recall file TESTB1 and plot it as Room 3. Finally recall TESTC1 and plot it as Room 4.

Press ESC to return to the plot menu. Now press R to plot results. The screen will clear and a plot showing the results for all four runs will be displayed. The concentration in Room 1 for Run 1 (TESTA1) will be displayed as Room 2, Run 2 as Room 3, Run 3 as Room 4, and the current run as Room 1.

Note that the time scale for all plots is based on the current calculation. If you recall data with a different time scale, the plot may look strange. Therefore, ensure that all calculations for a given situation cover the same time range. Use Set up to make sure.

The last menu option is Set up, which transfers control to a data entry form shown in Figure 3-31. The purpose of Set up is to modify various items that control the execution of the program. Each of these items is discussed below.



```
Set up defaults

======================================================================
       Item                                  Value
======================================================================
       Deltat                                  30
       Print step                              50
       Maxrooms                                10
       Maxsources                               6
       Maxtimes                               740
       Maxdays                                  1
       Hours for simulation                    24
```

Figure 3-31. Set up data entry.

Deltat--Deltat is the time step in seconds for the finite difference solutions. Too large a value of Deltat will result in numerical instability. A value of 30 is a good starting point. The program will warn you to decrease Deltat if numerical instability is detected.

Print step--Print step is the number of Deltat steps between printouts. The program works by storing variables for later printout. Computer memory limits the number of steps that can be printed. The default means that after every 50 Deltat steps, the calculated values will be saved for later printout. If you are looking at short time simulations, say a few hours, set print step to 5 or 10.

Maxrooms--Maxrooms is the maximum number of rooms allowed. You may have to reduce this depending on how much user available memory you have.

Maxsources--Maxsources is the maximum number of sources allowed in each room.

Maxtimes--Maxtimes is the dimension of the array that holds the calculated results for later printout. A value of 740 works on a machine with 640K RAM and no memory resident programs. You may have to reduce this if you have less RAM or memory resident programs.

Maxdays--Maxdays is the maximum numbers of days for the simulation.

Hours for simulation--This is the number of hours for the simulation when Maxdays = 1; e.g., if the simulation is to cover 4 hours, Maxdays = 1 and Hours for simulation = 4. If Maxdays > 1, then Hours for simulation = 24.

Examples

The best way to learn to use the model is to run several examples. The first example will lead you through most of the screens and the screens will be displayed. Later examples will present the input data and graphical output.

Example 1--single chamber study

To determine if the numerical procedures of the model were working properly, model predictions were compared to data from a single chamber study of kerosene heater NO emissions. The data for the example are:

Number of rooms 1
Room volume 27 m^3
Air exchange rate 0.39 ACH
Air flow to ambient 10.53 m^3/h
Air flow from ambient 10.53 m^3/h
Source strength 7830 kJ/h
Source on at time 0
Source off at time 1 hour

The data entry procedure for this example is:

From the DOS prompt, type INDOOR and press ENTER.
The screen will clear and the master menu of Figure 3-32 will be displayed.

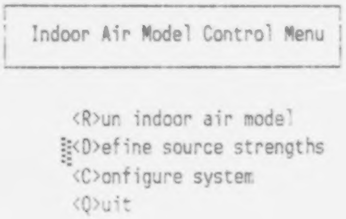
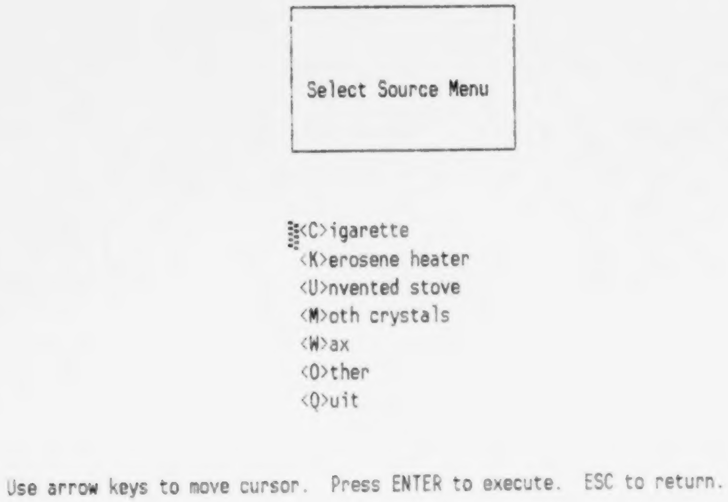


Figure 3-32. Master menu for example 1.

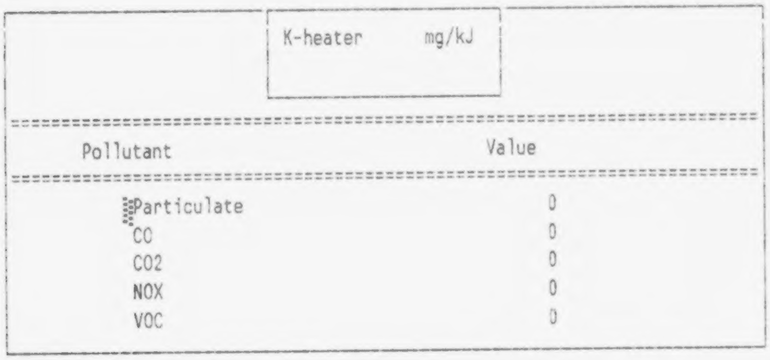
Press D to define the source strength. The screen will clear and Figure 3-33 will be displayed.


Select Source Menu
<C>igarette
<K>erosene heater
<U>nvented stove
<M>oth crystals
<W>ax
<O>ther
<Q>uit

Use arrow keys to move cursor. Press ENTER to execute. ESC to return.

Figure 3-33. Define source menu for example 1.

Select kerosene heater by pressing K. The data entry form in Figure 3-34 will be displayed.



```
                    K-heater      mg/kJ

=========================================================
     Pollutant                       Value
=========================================================
          Particulate                   0
          CO                            0
          CO2                           0
          NOX                           0
          VOC                           0
```

Figure 3-34. Source strength data entry for example 1.

Use the down arrow key to move the highlight bar to NOX, type 0.0237, and press ENTER. Now press ESC to return to the main source definition menu. Press Q to quit and return to the master menu.

Once back to the master menu, press R to run the indoor air model. The screen will clear and display the main control menu of Figure 3-35.

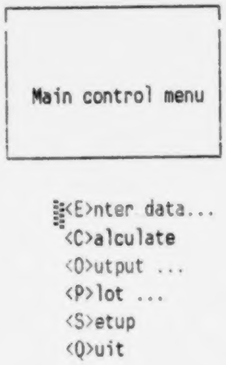

Main control menu
<E>nter data...
<C>alculate
<O>utput ...
<P>lot ...
<S>etup
<Q>uit

Figure 3-35. Main control menu for example 1.

Press E to enter data and to display data input menu Figure 3-36.

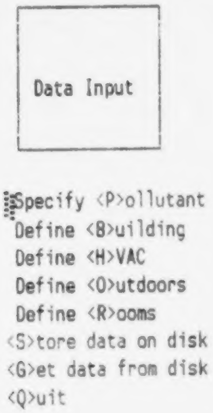
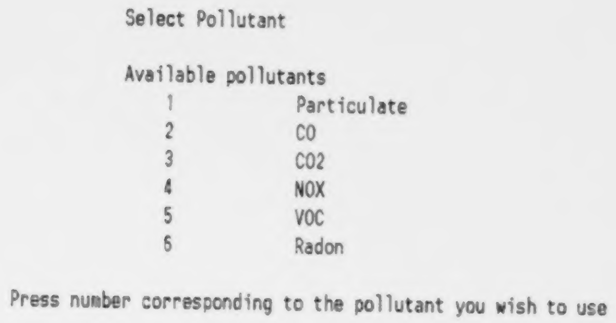

Data Input
Specify <P>ollutant
Define <B>uilding
Define <H>VAC
Define <O>utdoors
Define <R>ooms
<S>tore data on disk
<G>et data from disk
<Q>uit

Figure 3-36. Data input menu for example 1.

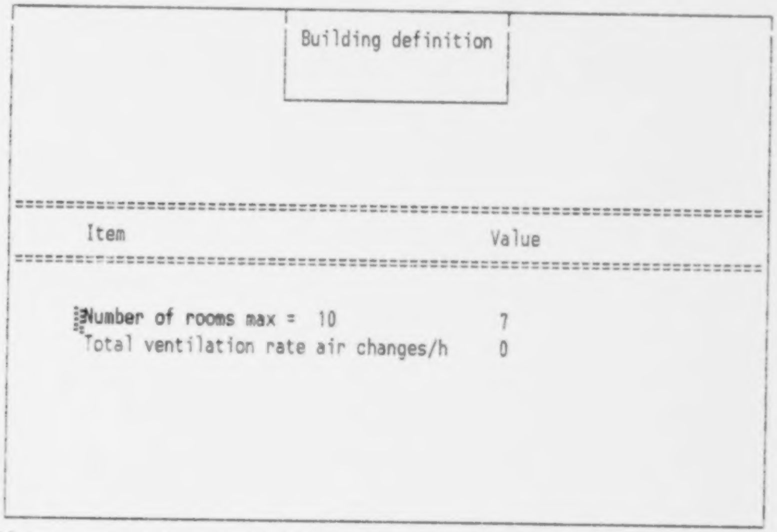
Press P to specify the pollutant and to get the menu shown in Figure 3-37. Press 4 for NOX. The program will return you to the data input control menu.



```
Select Pollutant

Available pollutants
    1          Particulate
    2          CO
    3          CO2
    4          NOX
    5          VOC
    6          Radon

Press number corresponding to the pollutant you wish to use
```

Figure 3-37. Select pollutant menu for example 1.

When you are back to the data entry control menu, press B (for define building) to display the building form, Figure 3-38. Use the cursor control keys to move the highlight bar over Number of rooms max. Type 1 and press ENTER. Use the down arrow key to move to total ventilation rate. Type 0.39 and press ENTER. Press ESC to return to the data entry control menu.

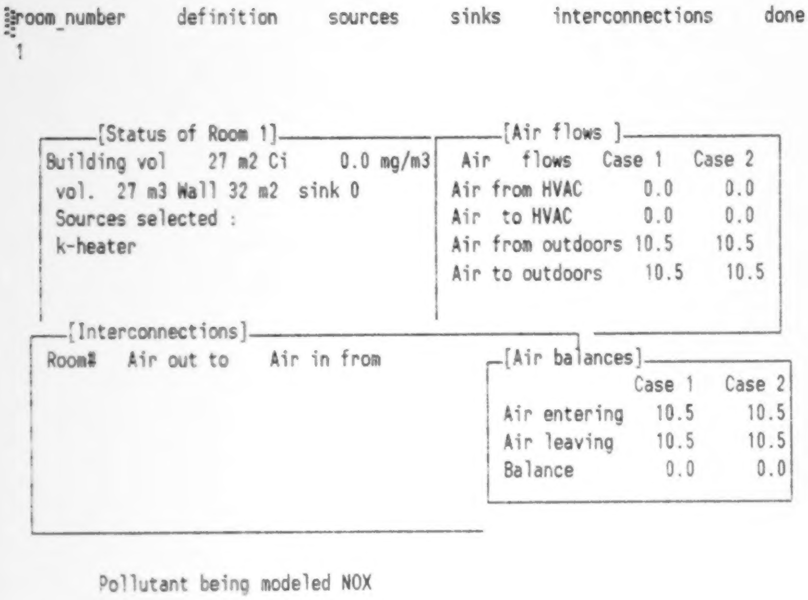


```
                    Building definition

==========================================================================
      Item                                        Value
==========================================================================

     Number of rooms max =  10                    7
     Total ventilation rate air changes/h         0
```

Figure 3-38. Building definition menu for example 1.

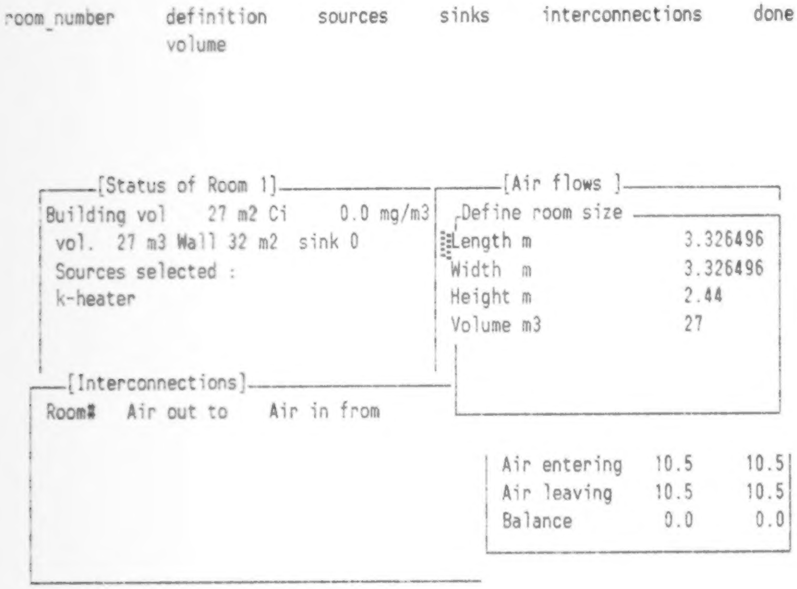
When you are back to the data entry control menu, press R to define the room and display the room definition screen, Figure 3-39.

Use the left and right arrow keys to move the highlight bar to definition; then use the down arrow key to move the highlight bar over volume. Press ENTER. The form for entering data on the room volume will be displayed on the screen, see Figure 3-40. Use the down arrow key to move the highlight bar to Volume and type 27. Press ENTER. Now press ESC to return to the main room form.



```
room_number    definition    sources    sinks    interconnections    done
1

 ____[Status of Room 1]__________  ____[Air flows ]______________
|Building vol    27 m2 Ci      0.0 mg/m3| Air   flows    Case 1   Case 2 |
| vol.  27 m3 Wall 32 m2  sink 0        | Air from HVAC     0.0      0.0 |
| Sources selected :                    | Air  to HVAC      0.0      0.0 |
| k-heater                              | Air from outdoors 10.5    10.5 |
|                                       | Air to outdoors   10.5    10.5 |
 __[Interconnections]______________________
| Room#   Air out to     Air in from      __[Air balances]_________
|                                        |            Case 1   Case 2|
|                                        | Air entering   10.5    10.5|
|                                        | Air leaving    10.5    10.5|
|                                        | Balance         0.0     0.0|
|________________________________________|

        Pollutant being modeled NOX
```

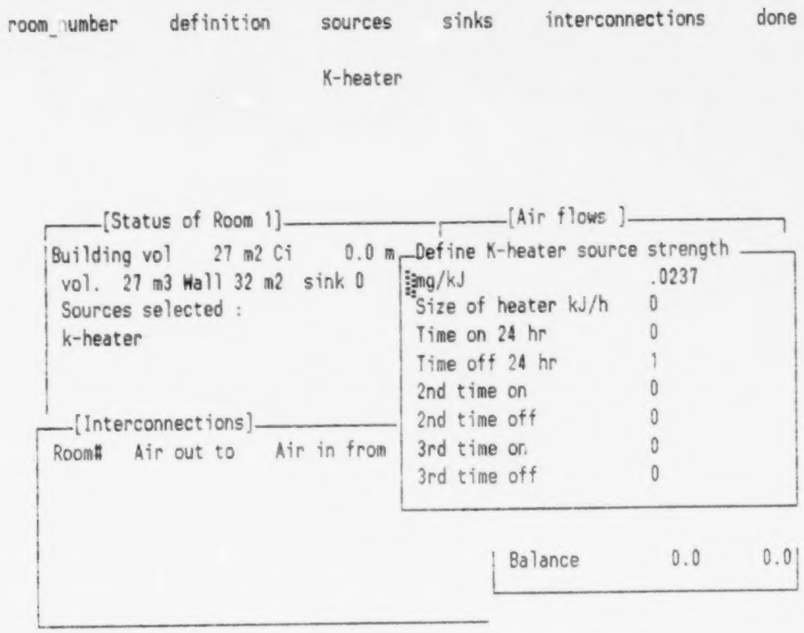
Figure 3-39. Room definition screen for example 1.



```
room_number    definition    sources    sinks    interconnections    done
               volume


 ____[Status of Room 1]__________  ____[Air flows ]______________
|Building vol    27 m2 Ci      0.0 mg/m3| Define room size ____________
| vol.  27 m3 Wall 32 m2  sink 0        |Length m           3.326496 |
| Sources selected :                    | Width  m          3.326496 |
| k-heater                              | Height m          2.44     |
|                                       | Volume m3         27       |
 __[Interconnections]____________________|
| Room#   Air out to     Air in from    |__________________________|
|
|                                        | Air entering   10.5    10.5|
|                                        | Air leaving    10.5    10.5|
|                                        | Balance         0.0     0.0|
|________________________________________|
```

Figure 3-40. Room volume screen for example 1.

Use the left and right arrow keys to move the highlight bar over sources. Use the down arrow key to move the highlight bar to k-heater and then press ENTER. The source definition form will be displayed as shown in Figure 3-41.

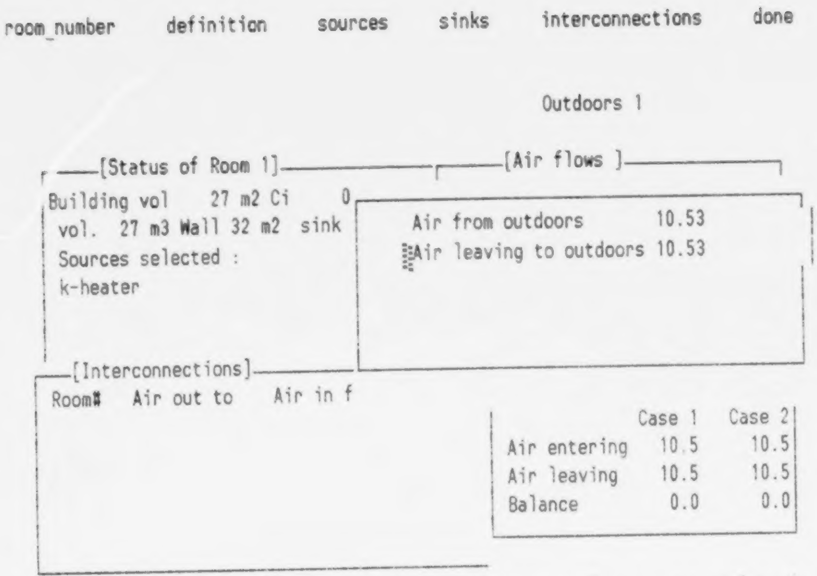


```
room_number   definition   sources   sinks   interconnections   done

                           K-heater


 ┌────[Status of Room 1]──────────┌────────[Air flows ]──────────┐
 |Building vol   27 m2 Ci    0.0 m─Define K-heater source strength ──
 | vol.  27 m3 Wall 32 m2  sink 0 |mg/kJ                 .0237
 | Sources selected :             | Size of heater kJ/h   0
 | k-heater                       | Time on 24 hr         0
 |                                | Time off 24 hr        1
 |                                | 2nd time on           0
 ──[Interconnections]─────────────| 2nd time off          0
 Room#   Air out to    Air in from| 3rd time on           0
 |                                | 3rd time off          0
 |                                └──────────────────────────────┘
 |
 |                                   | Balance        0.0      0.0|
 |                                   └────────────────────────────┘
 └────────────────────────────────────
```

Figure 3-41. Define kerosene heater screen for example 1.

Use the up and down arrow keys to move the highlight bar over Size of heater kJ/h, type in 7830, and press ENTER. Use the down arrow key to move the highlight bar to Time on, type 0, and press ENTER. Use the down arrow key to move the highlight bar to Time off, type 1, and press ENTER. Review the data you entered. If you made an error, use the up and down arrow keys to move the highlight bar to the data item that is in error. Type in the correct value. When all the data are correct, press ESC to return to the room definition form.

Use the left and right arrow keys to move the highlight bar over Interconnections. Then use the down arrow key to move the highlight bar over Outdoors 1 and press ENTER. This will display the interconnection with the outdoors data form, Figure 3-42.



```
room_number    definition    sources    sinks    interconnections    done

                                        Outdoors 1

 ——[Status of Room 1]——————————  ————[Air flows ]——————————
 Building vol    27 m2 Ci     0
  vol.  27 m3 Wall 32 m2  sink    Air from outdoors        10.53
  Sources selected :              Air leaving to outdoors 10.53
  k-heater

 —[Interconnections]——————————
 Room#   Air out to    Air in f
                                                  Case 1    Case 2
                                  Air entering    10.5      10.5
                                  Air leaving     10.5      10.5
                                  Balance          0.0       0.0
```

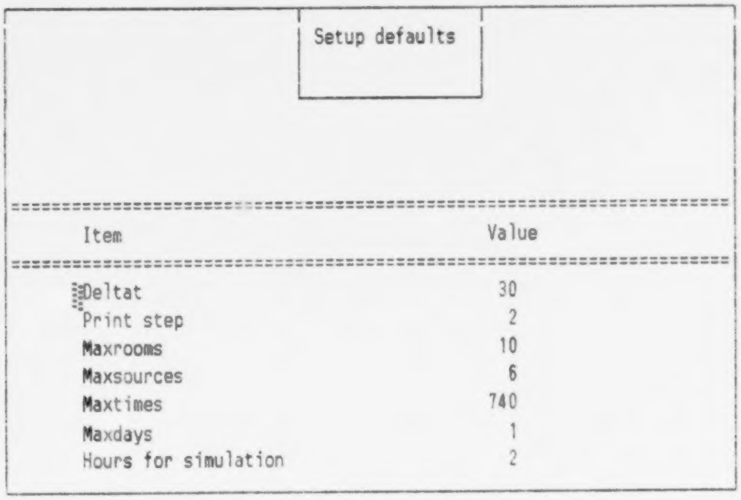
Figure 3-42. Air flow to outdoors for example 1.

Note that the air flows to and from the outdoors have been calculated by the program based on the air exchange rate specified in the building definition. If the air from the outdoors is not 10.53, use the down arrow key to place the highlight bar over Air from outdoors, type 10.53, and press ENTER. Do the same for air leaving. Press ESC to return to the main room definition form.

Ensure that the balance for the air flows is zero. If it is not, you have made an error in the interconnections data entry and should reenter the data.

Ensure that all the room data are correct. Either press ESC or move the highlight bar to done and press ENTER to return to the data entry control menu. Press ESC to return to the main menu.

Press S for setup and get the setup form, Figure 3-43, on the screen.



```
                          Setup defaults

=====================================================================
       Item                                  Value
=====================================================================
       Deltat                                 30
       Print step                              2
       Maxrooms                               10
       Maxsources                              6
       Maxtimes                              740
       Maxdays                                 1
       Hours for simulation                    2
```

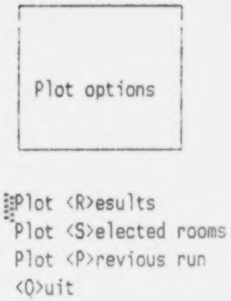
Figure 3-43. Setup form for example 1.

Use the cursor key to move the highlight bar over Maxdays and then enter 1. Then move the highlight bar to Hours for simulation and enter 2. This sets up the program to calculate the concentrations for 2 hours. Press ESC to return to the main menu. (Change the other numbers to agree with those shown in the figure if necessary.)

Now press C to calculate the results of the model run.

While the model is calculating, a simple bar graph of pollution is shown. This graph is intended to give a general indication of the relative pollution concentrations in the various rooms. It is not an exact indication of the pollution levels in the rooms. Note that the cumulative emissions and cumulative mass leaving the building are also printed.

When the model has completed its calculations, the main menu is displayed. Press P to obtain the plot menu, shown in Figure 3-44. Press R to plot the results. A screen dump of the plot is shown in Figure 3-45. Note that the concentrations are plotted on a log scale.



```
Plot options

Plot <R>esults
Plot <S>elected rooms
Plot <P>revious run
<Q>uit
```

Figure 3-44. Plot menu for example 1.

The results of the calculations are compared with the experimental results of Traynor, et al.(1983) in Figure 3-46. (Note that the plot in Figure 3-46 is linear-linear and the plot in Figure 3-45 is semi-log.) The agreement with the experimental data is quite good. This result indicates that the model is operating correctly in a numerical sense.

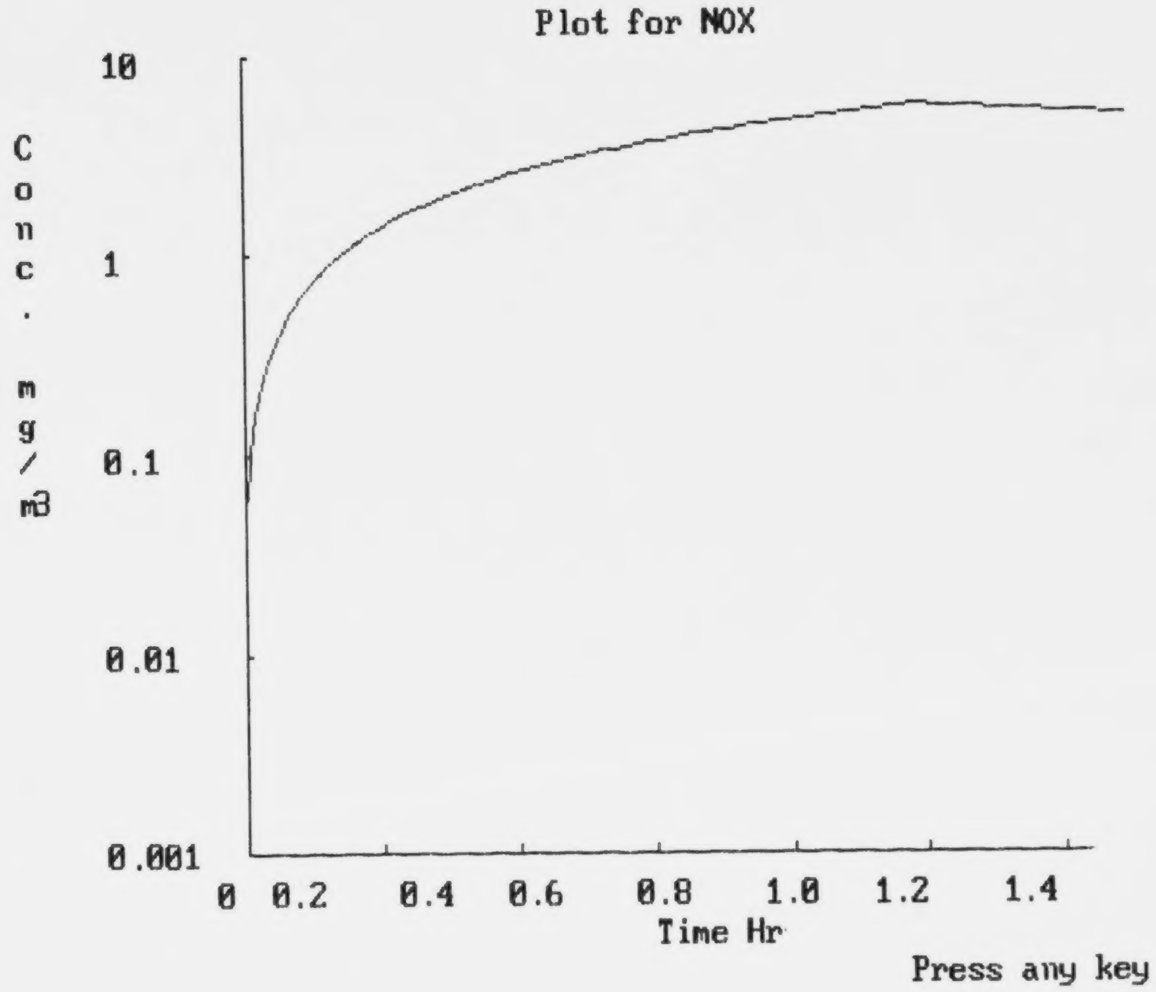


Figure 3-45. Screen dump of plot from example 1.

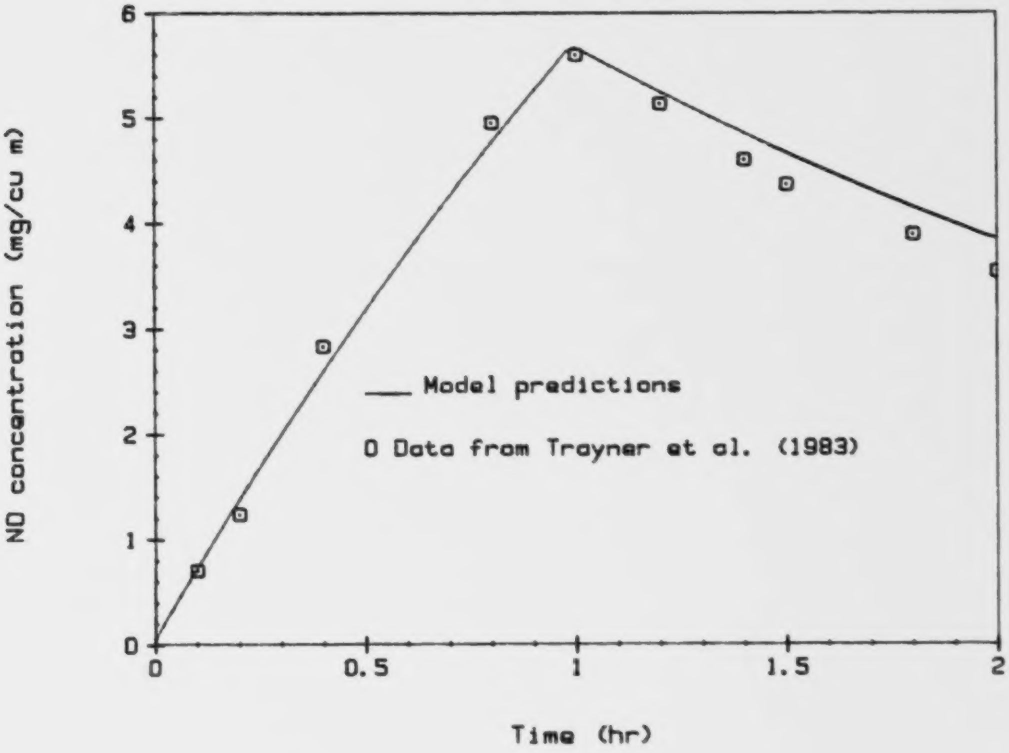


Figure 3-46. Comparison of model calculations with Traynor, et al.

Example 2--multiple chamber study

This example is for a multiple room situation and is taken from Axley (1987). The rooms in the building are connected by the HVAC system. The HVAC system is a small volume system.

Air flows are shown in Figure 3-48. The source is located in Room 1 and has a source strength of 550,000 mg CO_2/h. The source is operated for 130 minutes and then turned off. We want to model 4 hours.

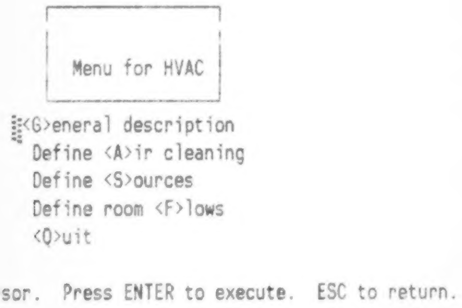
Step by step instructions are given for this example. However, the data entry screens are not shown.

From the DOS prompt, type indoor to get the master menu. Since the source term is not in normal units, do not use the Define source strengths option. Press R to run the indoor air model and get the main indoor model menu.

Press E to enter data. Specify the pollutant as CO_2. Press S to get the setup menu. Because the HVAC system is a very small volume system, a small time step is needed to ensure numerical stability. Enter 5 for Deltat and enter 30 for print step. Enter 1 for Maxdays and 4 for Hours for simulation. Press ESC to return to the data entry control menu.

Press B to define the building. Enter 4 for number of rooms. Enter 0 for ventilation rate. The ventilation rates will be defined for individual rooms when room data are entered. Press ESC to return to the data entry control menu.

Press H to get the HVAC menu (Figure 3-47). Press G to define the general HVAC system. Enter 1 for fraction of time on. Enter 1.1 for volume and 0 for makeup air.



Menu for HVAC

<G>eneral description
Define <A>ir cleaning
Define <S>ources
Define room <F>lows
<Q>uit

Use arrow keys to move cursor. Press ENTER to execute. ESC to return.

Figure 3-47. HVAC Menu for example 2.

Press F to enter room flows. The room flow data entry form is shown in Figure 3-49. Fill in the form as shown in Figure 3-49.

Press ESC when done to return to the HVAC menu. Press ESC to return to the data entry control menu.

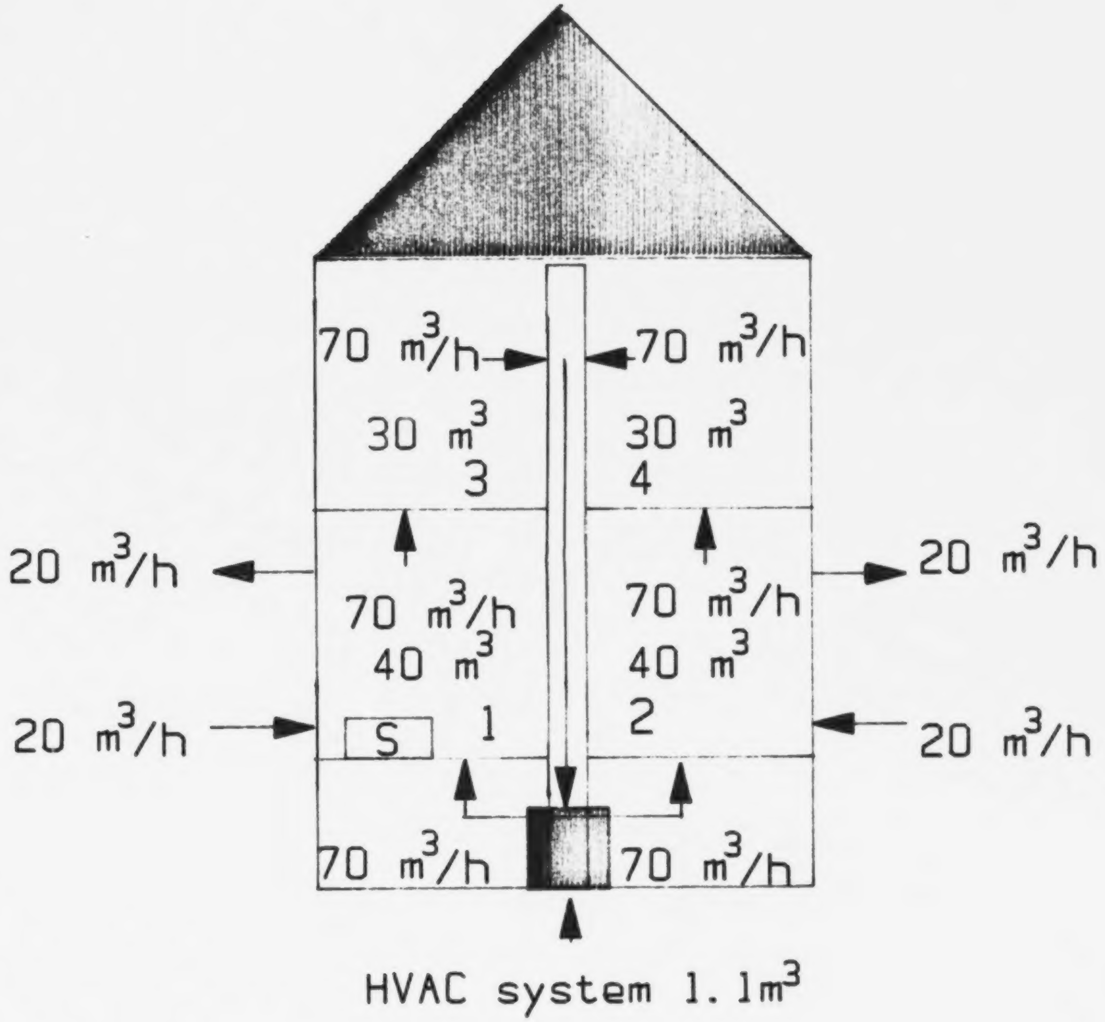
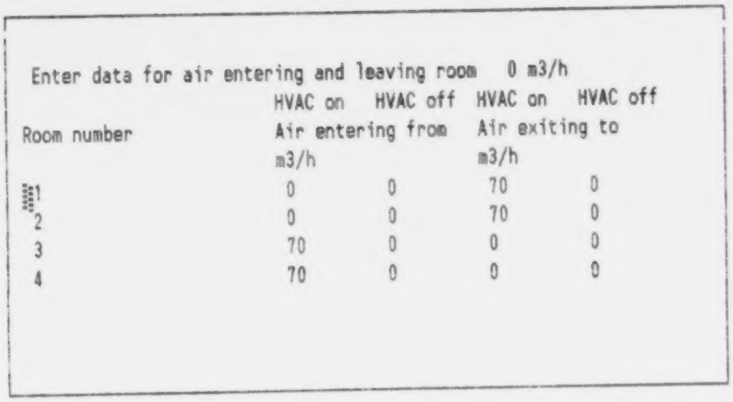

70 m^3/h
70 m^3/h
30 m^3
3
30 m^3
4
20 m^3/h
70 m^3/h
40 m^3
70 m^3/h
40 m^3
20 m^3/h
20 m^3/h
S
1
2
20 m^3/h
70 m^3/h
70 m^3/h
HVAC system 1.1m^3

Figure 3-48. Building for example 2.



```
Enter data for air entering and leaving room   0 m3/h
                         HVAC on   HVAC off  HVAC on   HVAC off
Room number              Air entering from   Air exiting to
                         m3/h                m3/h
1                          0         0         70         0
2                          0         0         70         0
3                          70        0         0          0
4                          70        0         0          0
```

Figure 3-49. HVAC data entry form for example 2.

Press R to define the rooms.

Select Room 1 and enter the volume (40 m^3). Now enter the source data for Room 1. Select K-heater and enter 550,000 as the source strength. Enter 1 for the size of heater. Enter 0 for time on and 2.167 for time off. Press ESC.

Now move highlight bar to interconnections. Use down arrow key to move highlight bar to Outdoors 1 and press ENTER. Enter 20 m^3/h for both air entering and air leaving. Press ESC.

Move highlight bar to other rooms and press ENTER. Use arrow keys to move to air to Room 4 and enter 70 as air out. Press ESC when done.

Check to see that the balance of air flows is zero.

Repeat data entry for the remaining rooms.

Run the program.

A plot of the model predictions and a comparison with the results of Axley (1987) are shown in Figure 3-50. Note that the model predictions agree with the calculations of Axley. This is further indication that the numerical procedures in the model are working properly.

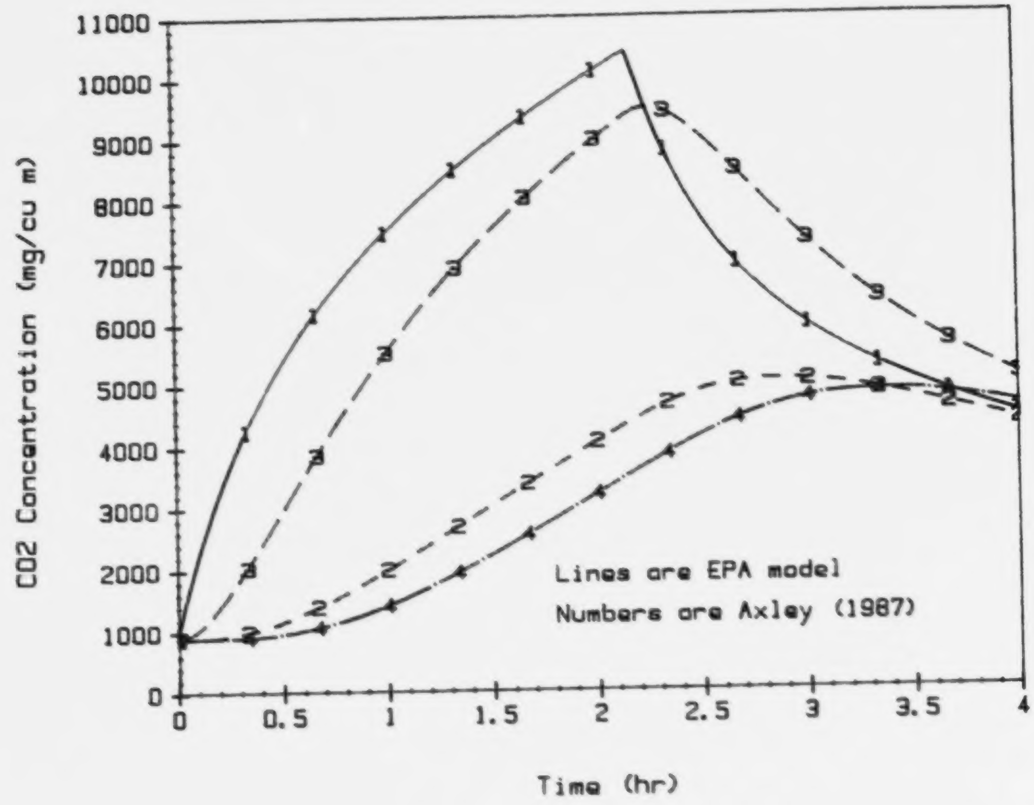


Figure 3-50. Comparison of results with Axley (1987) calculations.

SECTION 4.
CASE STUDIES

This section presents a series of case studies demonstrating the use of the model. The case studies are based on real indoor air situations and data. The results of these studies show that the model predictions are close to measured data even where very little is known about room-to-room flows.

Case Study 1. Particulate Loading in an Office Building

The model was used to estimate particulate loading due to smoking in an office building. The building floor plan in shown in Figure 4-1. The rooms with smokers are marked with an S. The ventilation design for the building is based on 10% makeup air in the HVAC system and no additional outdoors air infiltration. Each room is supplied with HVAC air. The HVAC return vents are located in the hall. The areas in the figure marked as not included are not served by the HVAC that serves the rest of the building. Therefore, these areas are not included in the modeling study.

Because there are more rooms in the building than are allowed in the model, some grouping of rooms is required. The grouping was based on:

1. The hall is a separate room because it contains the only return.
2. Adjacent rooms with smokers would be grouped.
3. Adjacent rooms without smokers would be grouped.

The result of the grouping is that the building was modeled as seven rooms with an HVAC system. Cigarette smoking was assumed to be the only source of pollution.

Data used in the model are shown in Table 4-1.

Table 4-1. Model input for case study 1

No. Rooms 7 No. Smokers 9 Makeup air 10%

Air cleaner efficiency 13%

Room #	Volume m^3	No. Smokers
1 (201,202)	84	0
2 (203-205)	126	3
3 (all others)	1008	0
4 (211,213)	84	2
5 (217)	42	2
6 (234,235)	84	2
7 (hall)		
Total		9

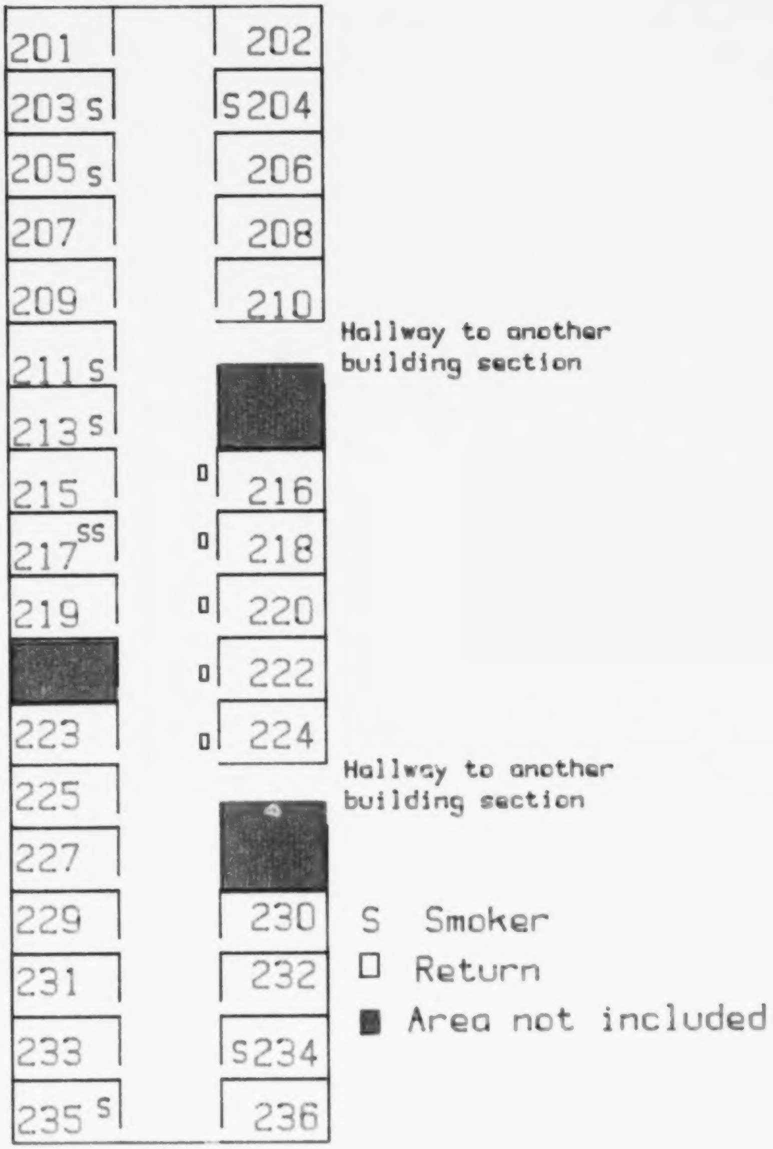

201
202
203 S
S 204
205 S
206
207
208
209
210
Hallway to another building section
211 S
213 S
215
216
217 SS
218
219
220
222
223
224
Hallway to another building section
225
227
229
230
231
232
233
S 234
235 S
236
S Smoker
☐ Return
■ Area not included

Figure 4-1. Building layout for case study 1.

Predictions of particulate concentrations in each room for a full day were desired. Cigarette smoking the the only source of particulate matter. Because the model does not allow repeated on and off smoking necessary to model the lunch hour, cigarette smoking was simulated by the unvented stove source type. This source type can be turned on and off three times a day and is thus adequate to simulate the lunch hour effects. The model predictions for design HVAC flows are shown in Figure 4-2.

Case Study 2. Random Cigarette Sources

The same building that was used for Case 1 was modeled with the random cigarette source for the first 4 hours. As can be seen from the results in Figure 4-3, the in-room peaks are very high when cigarettes are modeled as a short duration source.

The model predictions were used to estimate in-room average concentrations. These predicted time-averaged concentrations are compared to experimental data in Figure 4-4. The agreement between experiment and predictions is reasonable.

Both the predictions and the data show that particulate matter generated in a few offices is spread throughout the building. The particulate concentrations in all rooms exceed the proposed ambient air quality standard for respirable particulate matter of 50 $\mu g/m^3$.

Case Study 3. Effect of 13% Efficient Filter

The same building used above was used to estimate the effect of the 13% efficient filter on particulate loading in the building. As shown from the results in Figure 4-5, the filter had a significant impact on particulate concentrations.

The impact of the filter on particulate loading is due to the high circulation rate (12 ACH) through the filter.

Case Study 4. Filtering for $\leq$ 50 $\mu g/m^3$

Estimate the filter efficiency necessary to ensure that the particulate loading in all the rooms of the building is less than 50 $\mu g/m^3$ (the proposed PM-10 standard) . (The comparision with the proposed PM-10 standard is reasonable because the particles from smoking are all less than 10 mm in diameter.)

Solve this by running the program for filter efficiencies of 13, 50, 75, and 100%. Plot the particle concentration vs. efficiency and pick the required efficiency from the curve. See Figure 4-6.

Note that even with 100% filtration the rooms with smokers cannot be brought below 50 $\mu g/m^3$ even with the low assumed smoking rate of one cigarette per hour.

Case Study 5. No Room Exceeding 50 $\mu g/m^3$

Determine a method of allowing smoking in Case 4 with no room exceeding 50 $\mu g/m^3$ of particulate.

The Case 4 calculations showed that even 100% filtration efficiency in the central duct would not allow 50 $\mu g/m^3$ in the smoking rooms with the assumed fresh air makeup rate and the assumed air circulation rate. The loading in the smoking rooms could be reduced either by increasing the infiltration of outdoors air into the smoking rooms or by increasing the air circulation into and out of the smoking rooms. Model runs shown in Figure 4-7 show that a combination of 25% air infiltration and a doubling of the air circulation for the smoking rooms is necessary to achieve an average particulate concentration of 50 $\mu g/m^3$.

The peak concentrations in the smoking rooms greatly exceed the proposed PM-10 standard even under these conditions, Figure 4-8. A higher smoking rate would also result in particulate concentrations in excess of the proposed PM-10 standard.

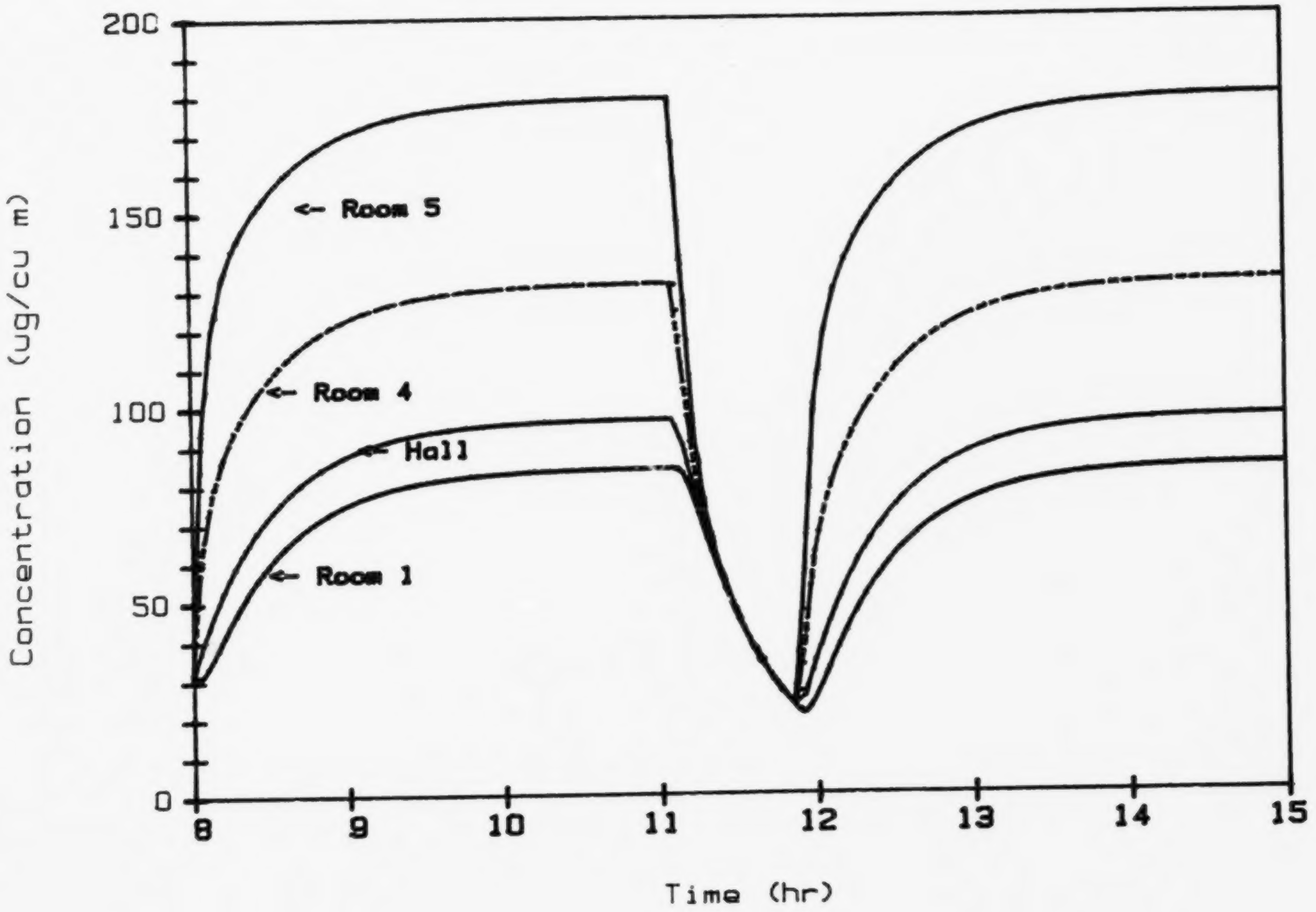


Figure 4-2. Model calculations for case study 1.

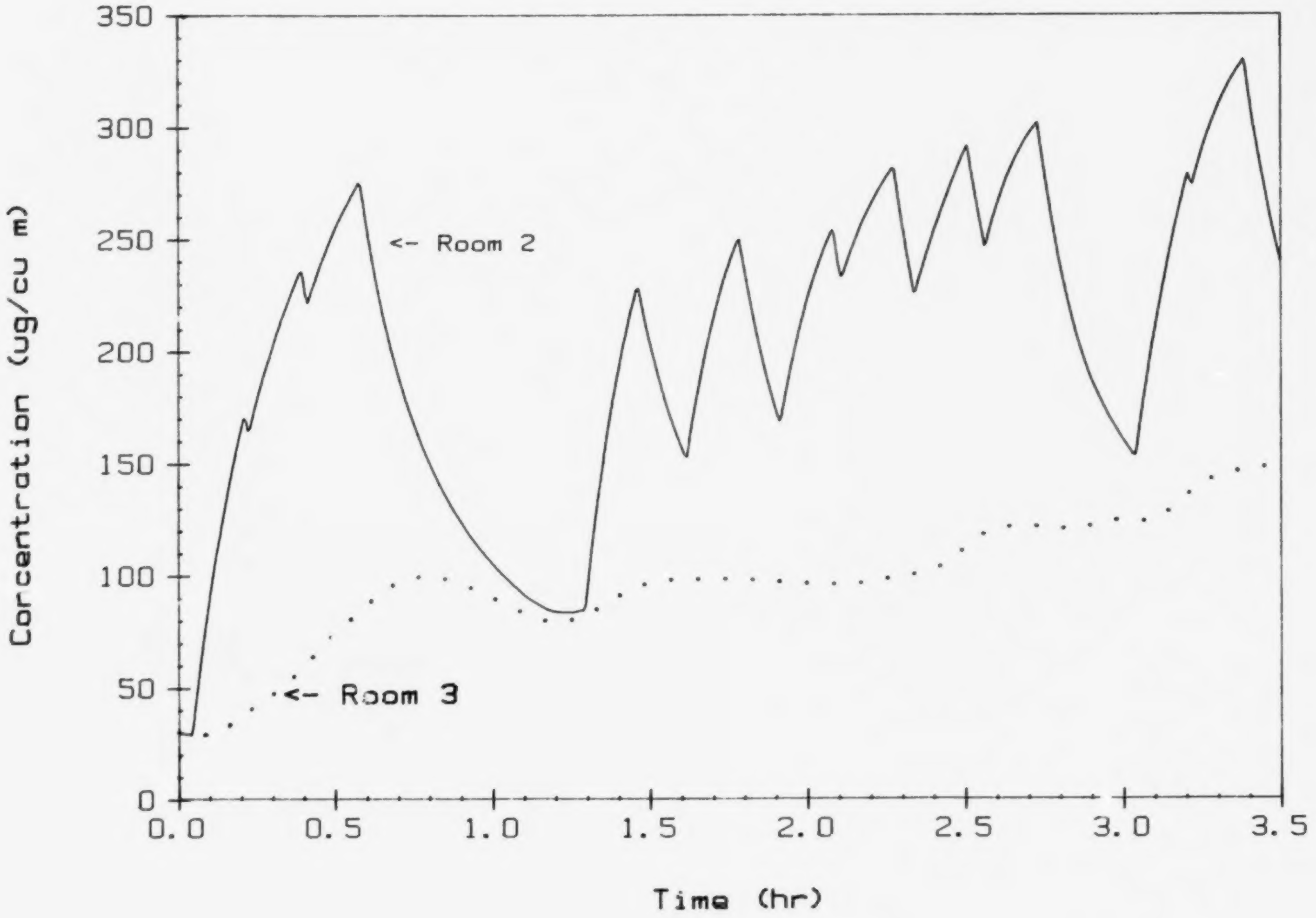


Figure 4-3. Particle concentrations for cigarette smoking.

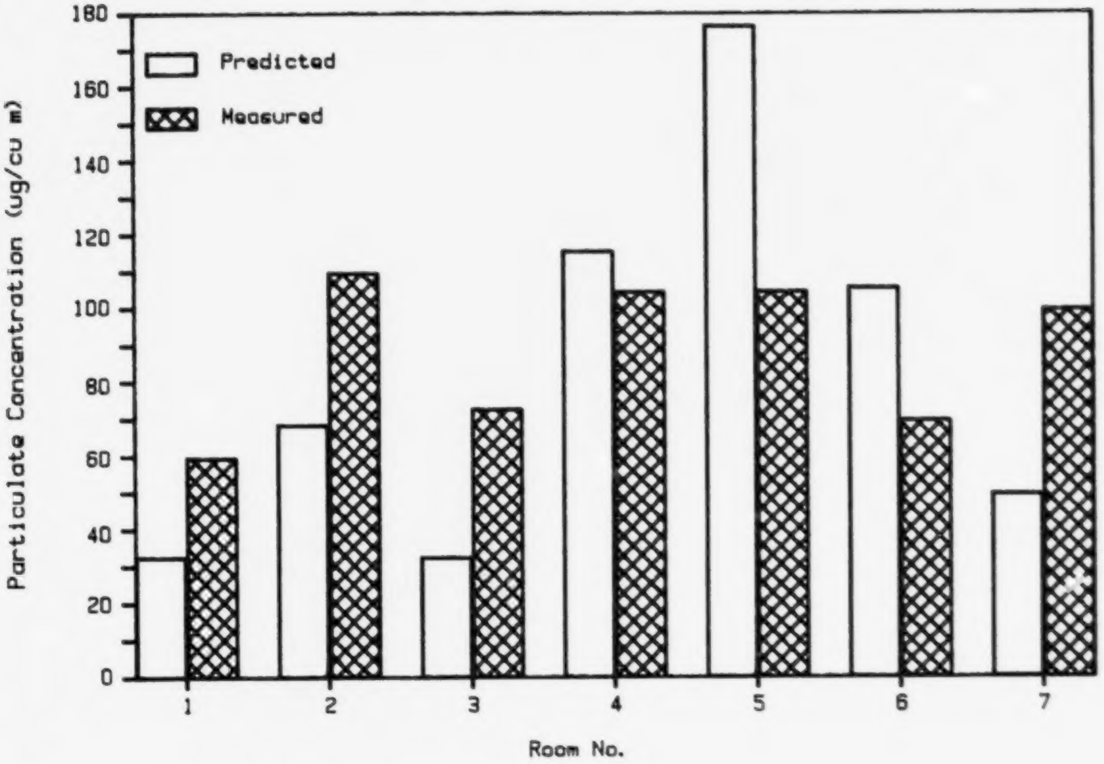


Figure 4-4. Comparision of predicted and measured results.

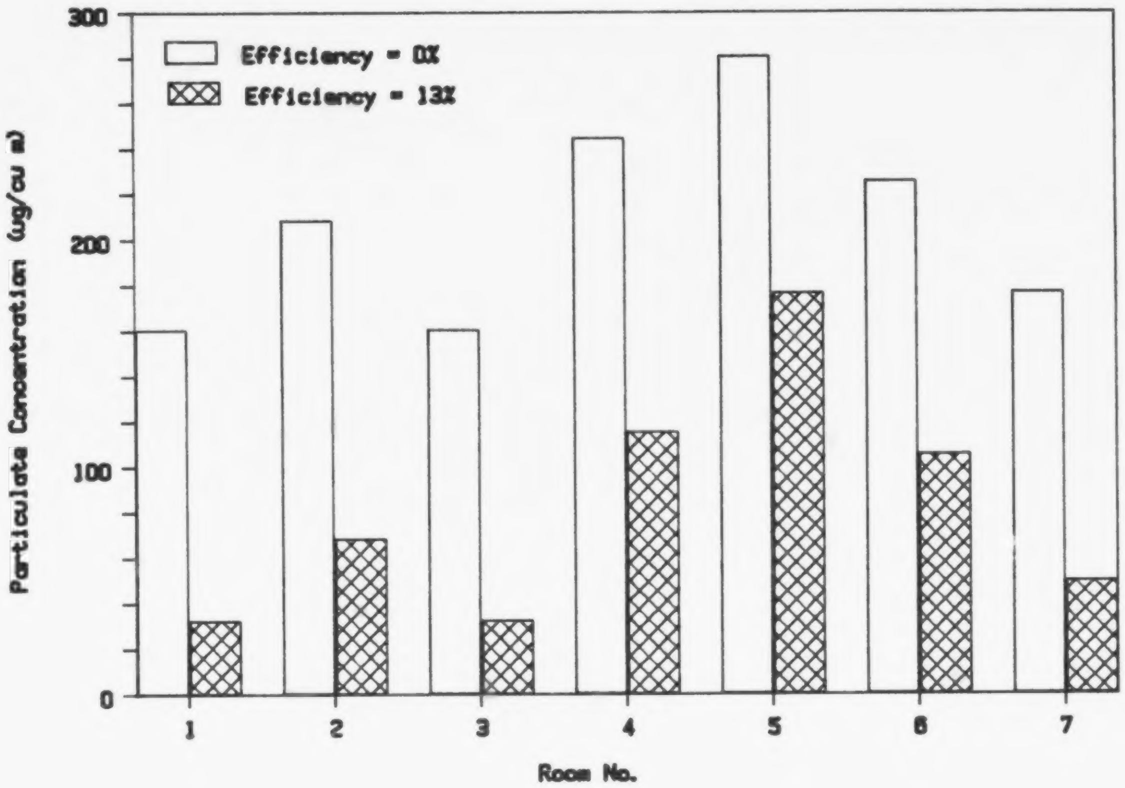


Figure 4-5. Effect of 13% efficient filter.

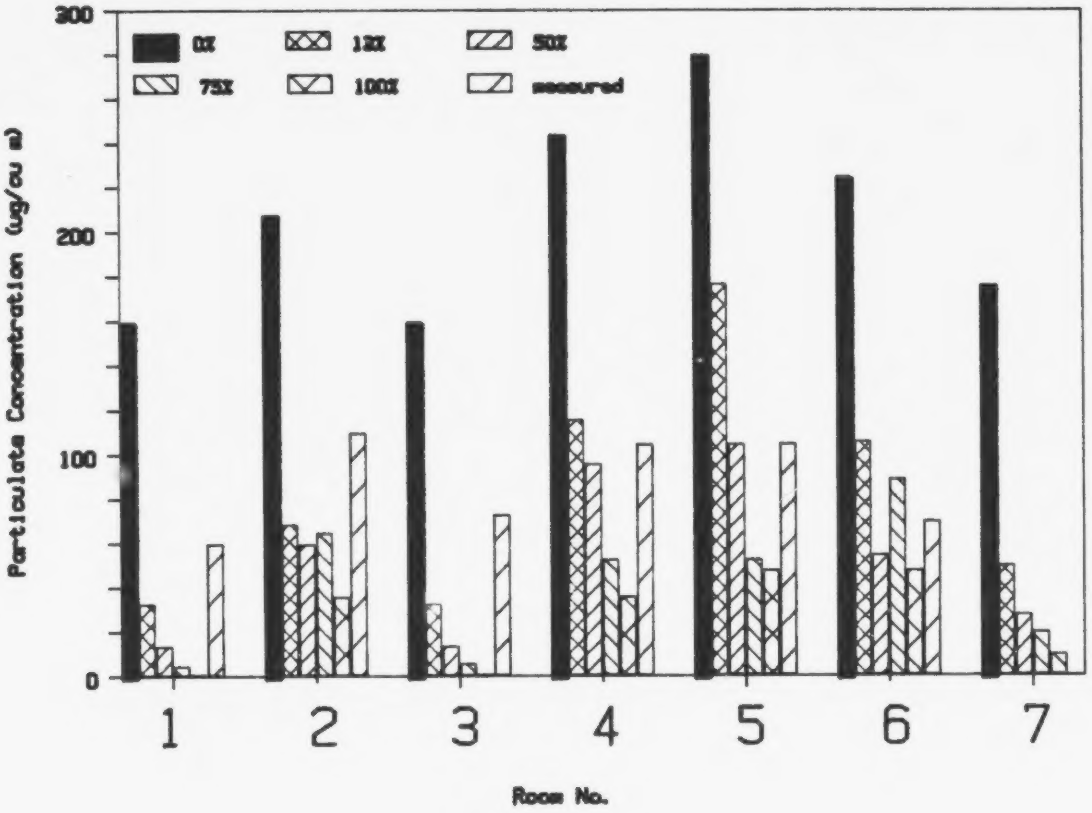


Figure 4-6. Effect of air cleaner efficiency.

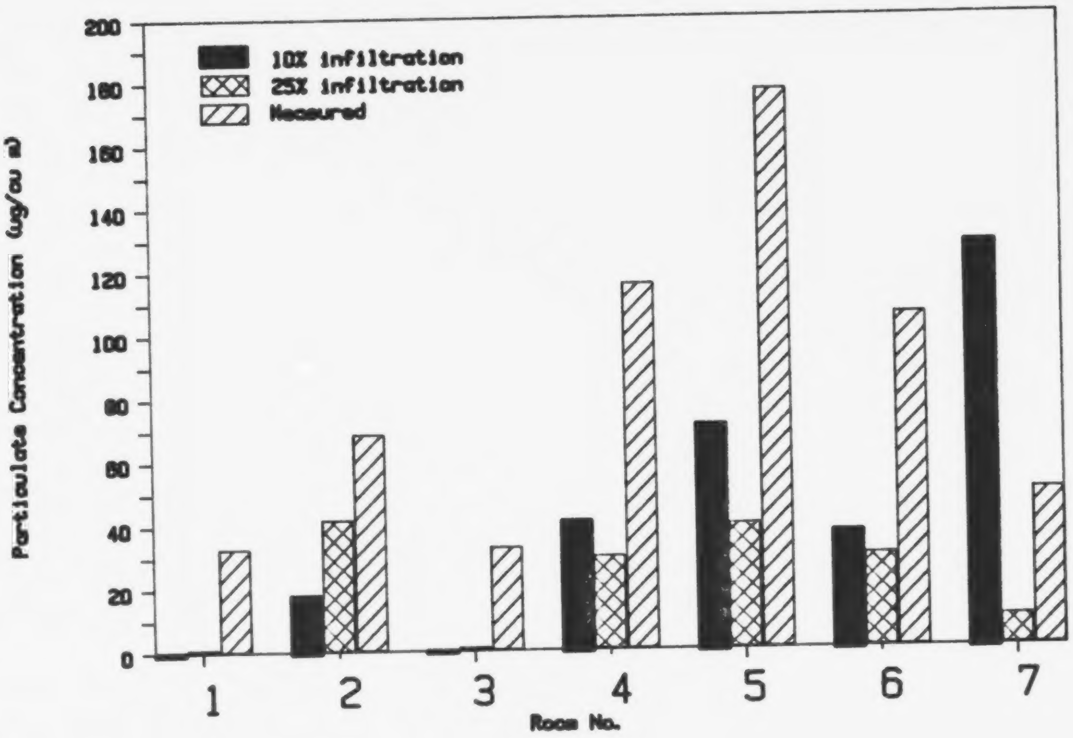


Figure 4-7. Results from case study 5.

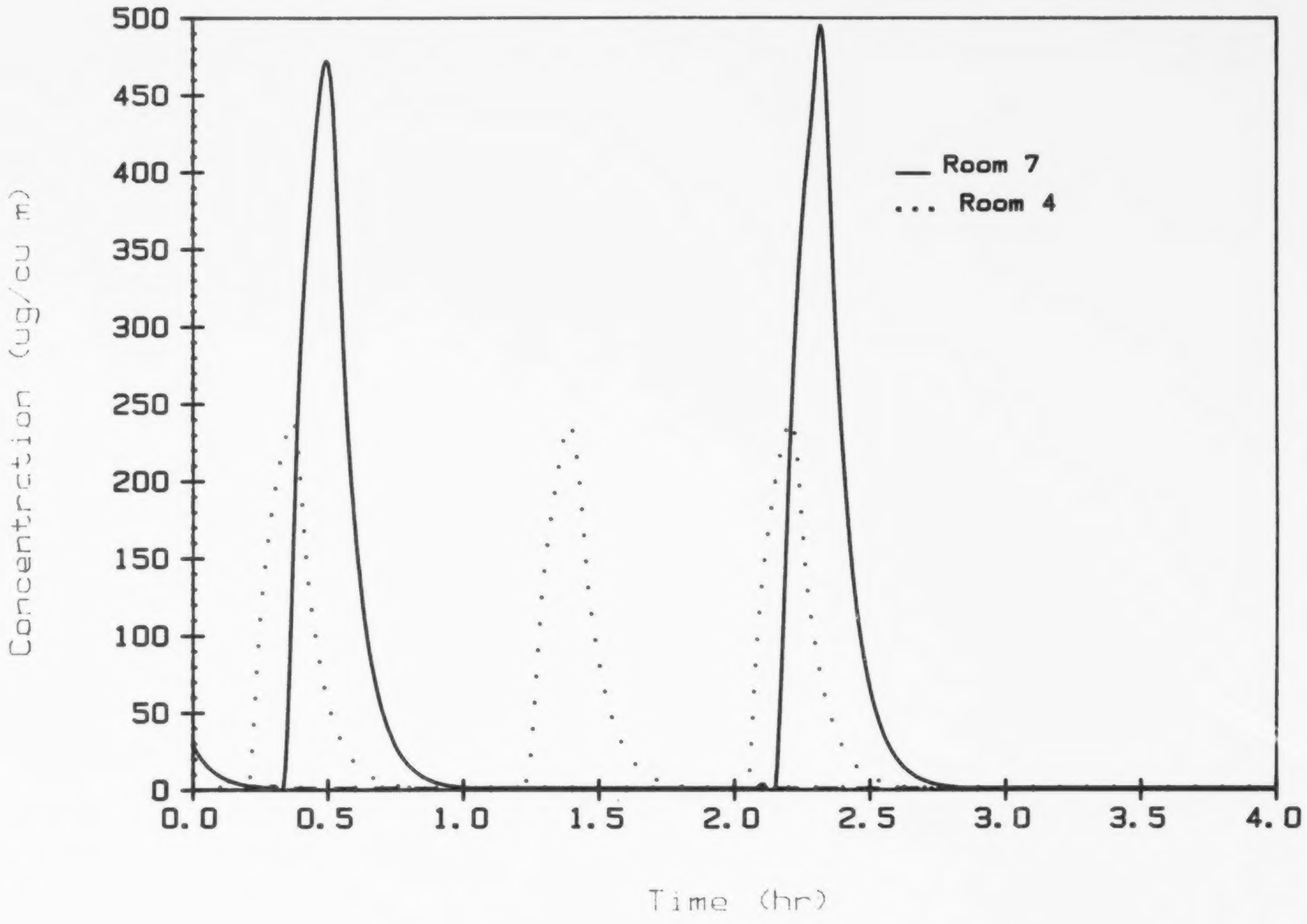


Figure 4-8. Instantaneous particulate concentrations.

Case Study 6. Analysis of Radon Entry Via Soil Gas

Radon is an important indoor air pollutant that generally enters the indoor environment via soil gas. The source of radon is the radioactive decay of radium. The radon gas is mixed with air in the soil. This air/radon mixture enters the building due to pressure driven flow. This case models the radon/soil gas situation for the simple building shown in Figure 4-9. Note that the radon decay is not modeled. (Future versions of the model will include the decay process.)

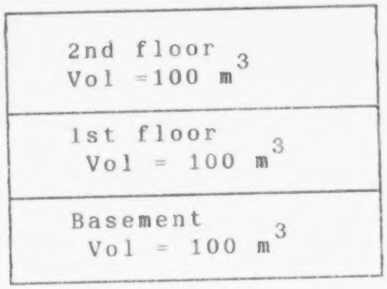


Figure 4-9. Building for case study 6.

The flows are 50 m^3/h between the first and second floors and 30 m^3/h between the first floor and the basement. Air at 50 m^3/h is exchanged with the outdoors for the first and second floors.

The soil gas entry problem can be modeled by adding an additional room that contains the radium source and a high radon gas concentration. The final sketch of the model building is shown in Figure 4-10.

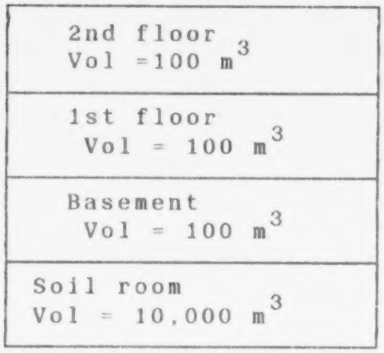


Figure 4-10. Final version of model building for case study 6.

The initial concentration of radon in the soil room is 80,000 pC/L. The soil gas room air flows are 10 m^3/h of air entering from the outdoors and 10 m^3/h entering the basement. The rest of the air flows in the building are now:

Basement to outdoors and outdoors to basement	0 m^3/h
Basement to first floor	40 m^3/h
First floor to basement	30 m^3/h
First floor to outdoors	50 m^3/h
Outdoors to first floor	50 m^3/h
First floor to second floor	60 m^3/h
Second floor to first floor	50 m^3/h
Second floor to outdoors	60 m^3/h
Outdoors to second floor	50 m^3/h

The initial concentration in all rooms in the building is 0 pC/L.

The model predictions for this situation are shown in Figure 4-11.

Case Study 7. Radon Driven by Building Depressurization

In many situations the radon gas flow into the building is driven by periods of depressurization of the building. This situation can be modeled by using the HVAC on/HVAC off flows provided by the model. For HVAC on (Case 1 flows) the flows in Case 6 are used. For HVAC off (Case 2 flows) the flows below are used:

Soil room to basement	0 m^3/h
Basement to soil room	0 m^3/h
Basement to and from outdoors	0 m^3/h
Basement to first floor	30 m^3/h
First floor to basement	30 m^3/h
First floor to and from outdoors	50 m^3/h
First floor to second floor	50 m^3/h
Second floor to first floor	50 m^3/h
Second floor to and from outdoors	50 m^3/h

The fraction of time on for the HVAC system is 0.1. Thus for 10% of the time in each hour, 10 m^3/h of soil gas enters the building.

The results of the modeling are shown in Figure 4-12.

Note that the modeling in Cases 6 and 7 for radon ignores the radioactive decay of radon. Also note that the results and techniques shown in these two examples can be used for pollutants other than radon, such as pesticides, that enter a building via soil gas.

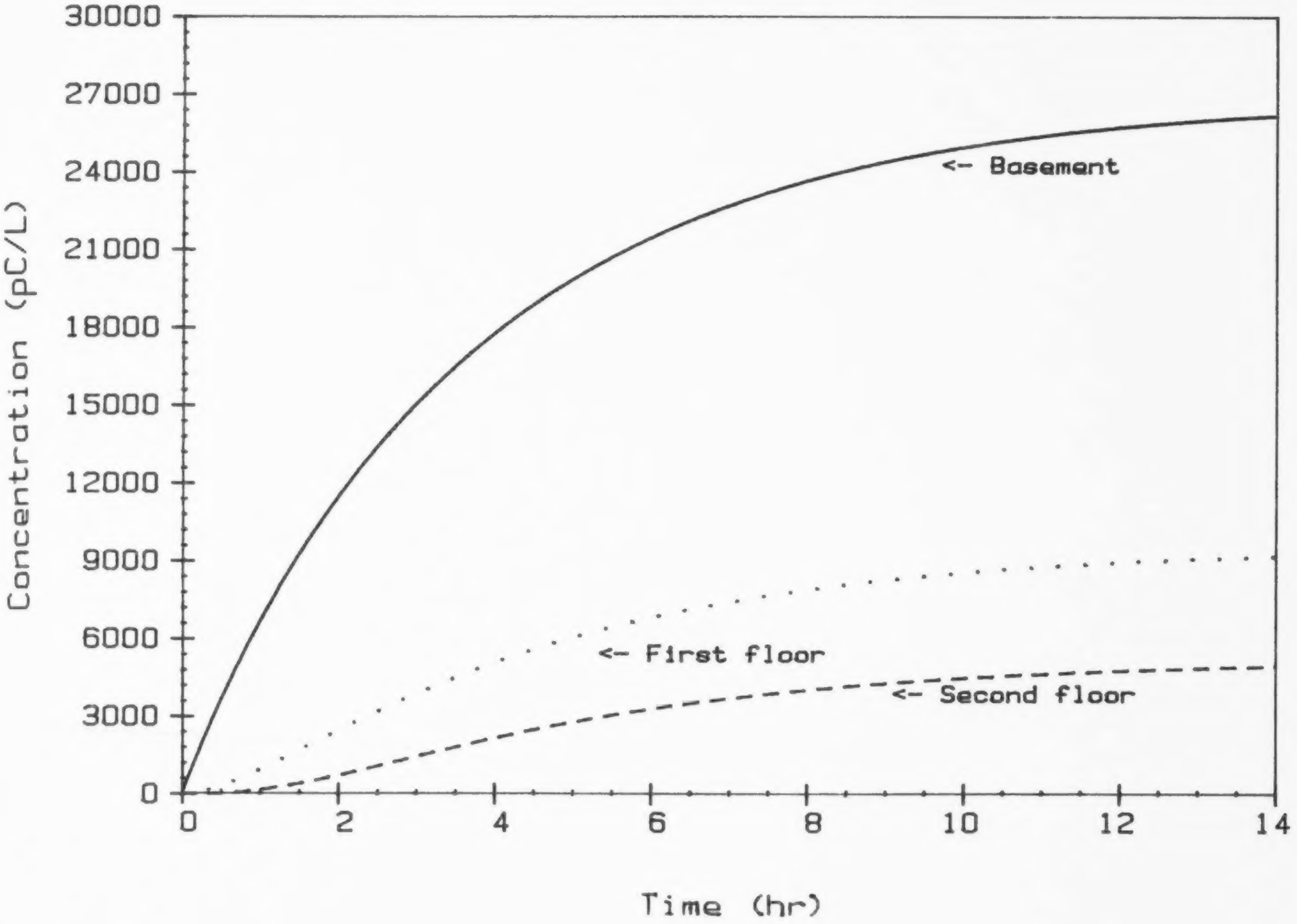


Figure 4-11. Calculated results for radon modeling.

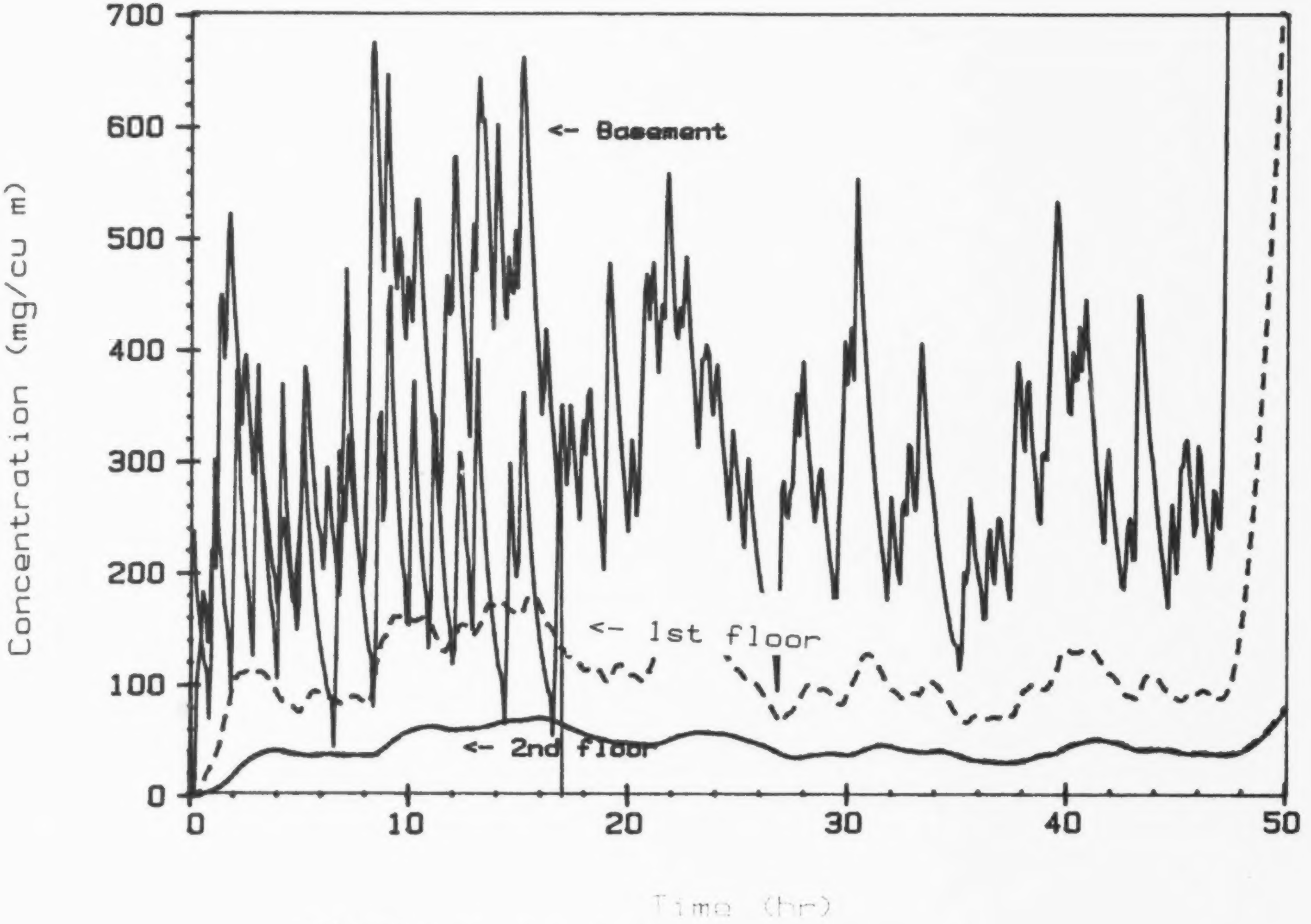


Figure 4-12. Calculated results for case 7.

SECTION 5.
APPLICATION OF MODEL TO IAQ TEST HOUSE

Introduction

This section describes case studies demonstrating the use of the model in an IAQ study. The case studies also demonstrate the use of small chamber emission factors in the model for predicting IAQ pollutant concentrations. The model is applied to fairly straightforward situations and to a situation where there is a reemitting sink. These data sets provide a good test of the model.

An objective of the indoor air program is to develop emission factors from small chamber studies that can be applied to full scale buildings. As part of this effort, AEERL is conducting small chamber and test house studies. One of the sources studied is moth crystals, the first source where AEERL emission factors and test house data are available.

Small Chamber Data

The emission factors for moth crystals were developed using 166 L test chambers. The basic components of the system, shown schematically in Figure 5-1, include the following sub-systems: clean air conditioning and delivery, Environmental Test Chambers (two at 166 L each), sampling manifolds, a sample concentration system using either Tenax or charcoal, and a permeation system for quality control standard addition. The environmental variables are monitored and controlled by a microcomputer (IBM PC) based system. Organic analyses are conducted by thermal desorption from Tenax traps to the concentrator column of a purge-and-trap device, followed by rapid thermal desorption to the column of a gas chromatagraph equipped with a flame ionization detector.

The p-dichlorobenzene emissions from the moth crystals were measured in the test chamber. The experimental techniques are described by Nelms et al.(1987). The emission factor developed by Nelms et al. for the conditions in the test house is 1.4 $mg/cm^2/h$.

Test House

AEERL has rented a three bedroom ranch style house to serve as a test house for IAQ studies. The floor plan of the test house is shown in Figure 5-2.

Blower door and SF6 tracer experiments were conducted to determine the air infiltration rates for the test house. These experiments established an infiltration rate of 0.35 ACH for the house under the conditions of the moth crystal studies.

For the moth crystal experiments, five cakes of moth crystals were placed in the closet in the corner bedroom. The moth crystals were laid on the shelves which reduced the surface area for emission by about 50% (from 980 to 570 cm^2). The air conditioning system operated continuously for the entire experiment.

Concentrations of p-dichlorobenzene were measured in the closet, in the corner bed room, in the master bedroom, and in the den. The p-dichlorobenzene measurements were made by direct injection into the GC. The measurements were made once a day for 4 days. The first measurement was made 3 days after the moth crystals were placed in the closet.

The results of the 4 days measurements are shown in Table 5-1.

Table 5-1. Results of p-dichlorobenzene measurements, mg/m^3

Day/Room	Closet	Corner Bedroom	Master Bedroom	Den
1	107	4.72	3.49	3.84
2	53.6	4.41	3.50	3.30
3	70.9	5.51	4.18	3.80
4	63.0	5.61	4.27	4.02
Average	73.6	5.06	3.86	3.74
Standard deviation	27.5%	10%	9.2%	7.1%

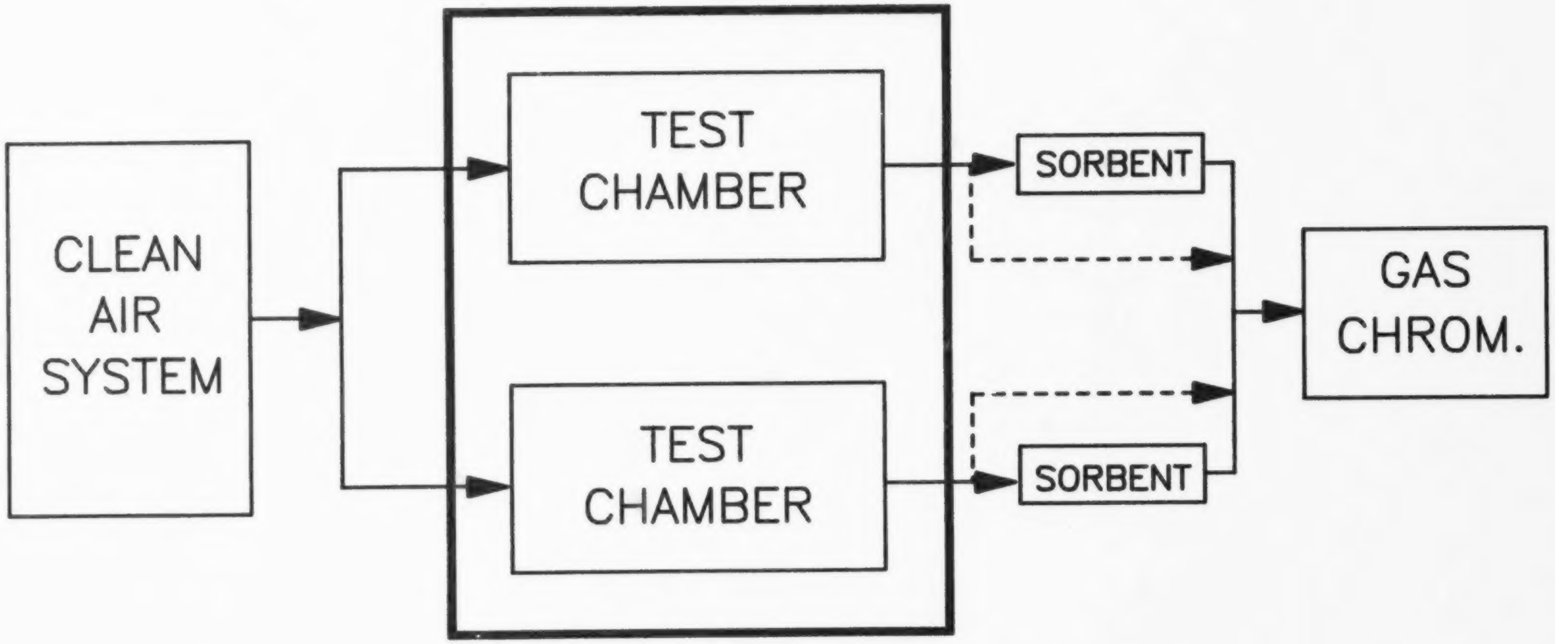

CLEAN
AIR
SYSTEM
TEST
CHAMBER
TEST
CHAMBER
SORBENT
SORBENT
GAS
CHROM.

Figure 5-1. Small chambers used for moth crystal studies.

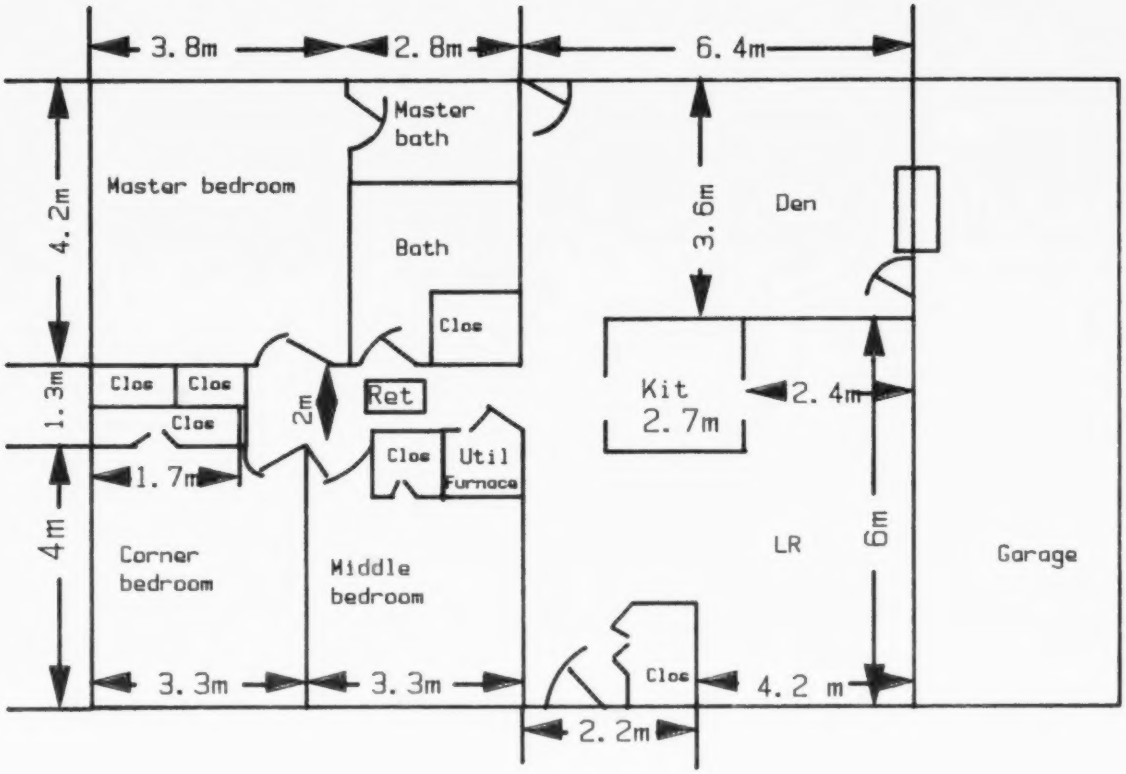

3.8m
2.8m
6.4m
Master bath
Master bedroom
4.2m
3.6m
Den
Bath
Clos
Clos
Clos
1.3m
Clos
2m
Ret
Kit
2.7m
2.4m
Clos
Util
Furnace
1.7m
4m
Corner bedroom
Middle bedroom
LR
6m
Garage
Clos
3.3m
3.3m
4.2 m
2.2m

Figure 5-2. AEERL IAQ test house.

Modeling

Several model calculations were run with a range of assumptions about flow from the closet and the effects of sinks. The model calculations were stopped after several hours of simulated time because steady state was reached. The model calculations are compared with the average measured concentrations in each room. The measurements are arbitrarily plotted at some time after steady state is reached. Each of the model runs is discussed below.

The input data for the first model run are shown in Table 5-2.

Table 5-2. Input data for initial moth crystal analysis

Source strength 1.4 $mg/cm^2/h$ from Nelms et al.(1987)
Air exchange with outdoors 0.35 ACH (SF_6 data)
Air exchange between closet and bedroom 0.5 m^3/h (assumed)
Air circulation to air handling system 7 ACH (rule of thumb)
All air flow to air handling system is from hallway.
Air exchange with outdoors is evenly divided between rooms.
Air handling system air is evenly distributed between rooms.
No sink effect.

The results of this run are shown in Figure 5-3. Note that the agreement between the model and the measured data is poor for the closet but reasonable for the other rooms. The model predictions for the closet are a factor of 20 too high and are a factor of 2 too high for the other rooms. The model also predicts too large a spread between the concentrations in the corner bedroom and those in the rest of the house.

The fact that the model predictions are all too high suggests that a sink is present. A run was made with the same data input as shown in Table 5-2 except that the sink factor was 1 m/h with no reemissions. This result is shown in Figure 5-4. The predicted and measured values of closet concentrations are in good agreement, but the other rooms are only 3 to 4% of the measured concentrations. Although there is certainly a sink for the p-dichlorobenzene, it is not the major cause of the relatively low p-dichlorobenzene concentration in the closet.

The in-closet concentrations can be reduced by allowing more air flow between the closet and the bedroom. Since the concentration in the closet needs to be reduced by over an order of magnitude, a good starting place is to increase the flow between the closet and the bedroom from 0.5 to 4 m^3/h. The model predictions for this situation (no sink) are shown in Figure 5-5. Note that, although the agreement between predictions and measurements is quite good, the model overpredicts the concentrations. Possible reasons for the overprediction are underestimation of air infiltration from outdoors and the presence of a sink.

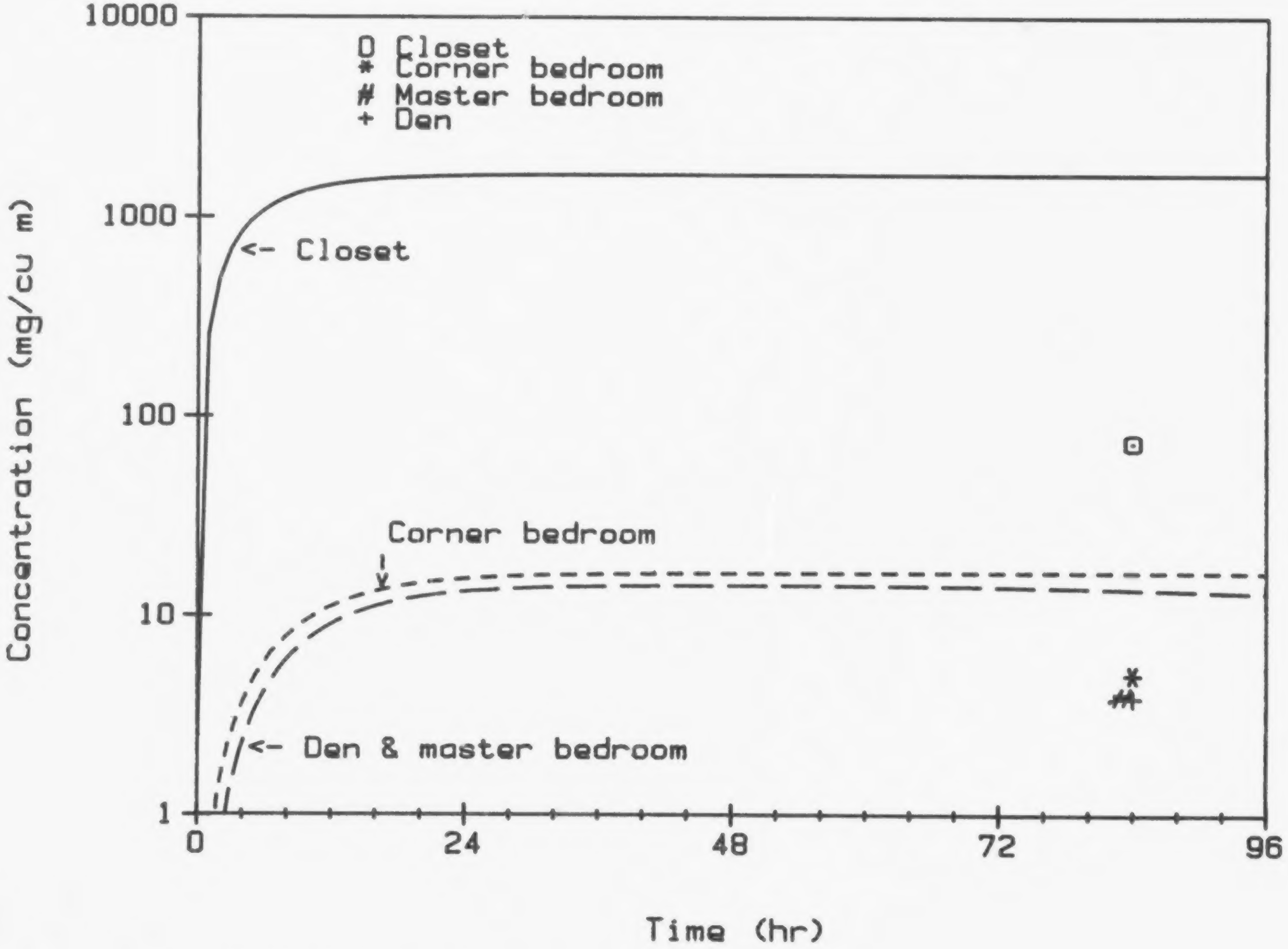


Figure 5-3. Initial model results.

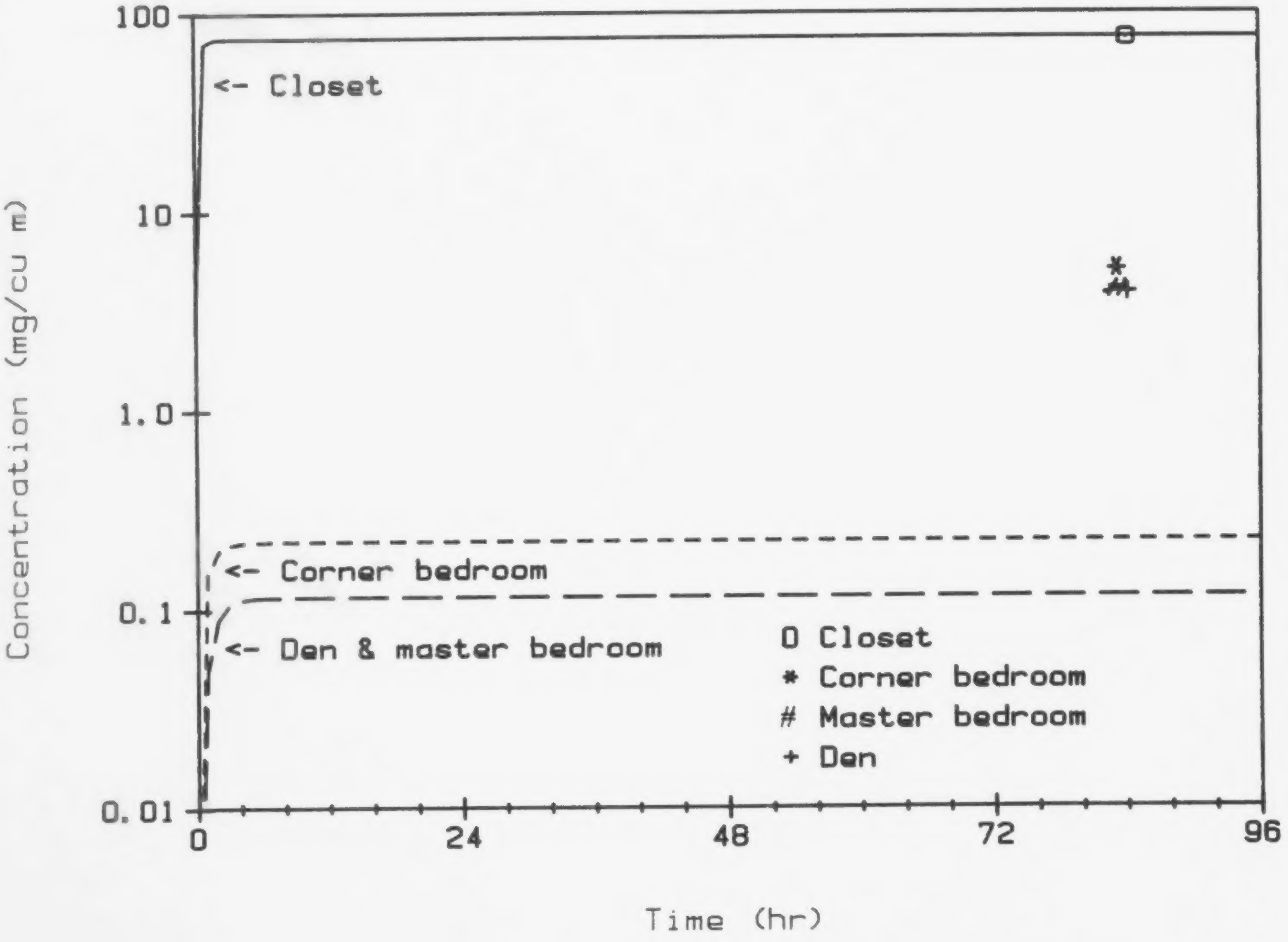


Figure 5-4. Model results with a large sink.

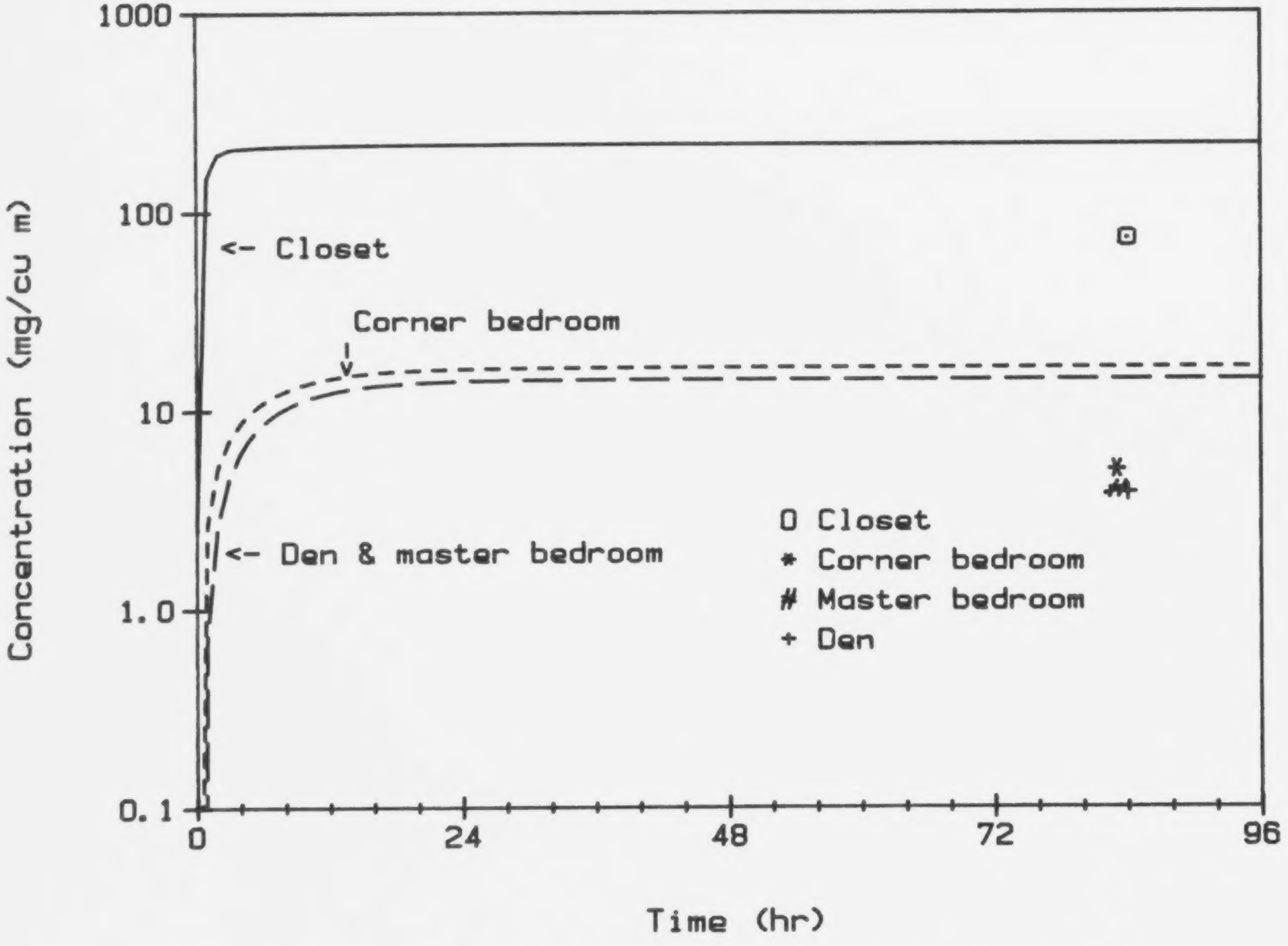


Figure 5-5. Model results with $4m^3/h$ flow from closet.

The SF_6 data indicate that the air infiltration is on the order of 0.35 ACH; thus, there is no reason to expect a major underestimation of air infiltration. The data for p-dichlorobenzene concentration after the moth crystals are removed clearly show that p-dichlorobenzene is being emitted. The most likely source of the emissions is a sink that has become a source.

The model was rerun with a sink rate of 0.35 m/h and no reemissions. (This results in the sinks' collecting about 50% of the total emissions.) The results of this run are shown in Figure 5-6. The agreement between the model and the data is quite good. Note, however, that the model underpredicts the p-dichlorobenzene concentrations in the den and master bedroom. The probable reason for this underprediction is that some of the closet air flow is directly exchanged with the hallway before it is mixed with the bedroom air. The floor plan for the house shows that the closet is next to the door to the hallway. Thus it is reasonable to assume that some of the air from the closet is exchanged directly with the hallway. As noted later the CO_2 data also support this conclusion.

The final model run, which includes a sink and flow between the closet and the hallway, is shown in Figure 5-7. Note that the agreement between model and data is excellent. A summary comparision of model predictions and measured data is shown in Table 5-3.

Table 5-3 Summary comparison of model predictions and measured data

	Ratio of predicted to measured concentration[a]			
Case	Closet	Corner Bedroom	Master Bedroom	Den
1	23	2.35	2.8	2.2
2	1.1	0.048	0.025	0.027
3	3	1.8	2.2	2.2
4	0.998	0.89	0.97	0.93

(a) Measured concentration is average of all measurements:
Case 1: Low flow from closet, no sink.
Case 2: Low flow from closet and large sink.
Case 3: 5 m^3/h flow from closet, no sink.
Case 4: Measured flows and moderate sink.

Conclusions from Modeling

The experimental data and the model predictions show that the small chamber emission factors for p-dichlorobenzene can be used with the model to estimate p-dichlorobenzene concentrations in a building. Even if the sink term is neglected, the agreement between predictions and experimental data is reasonable. The inclusion of the sink term brings the agreement within 15%.

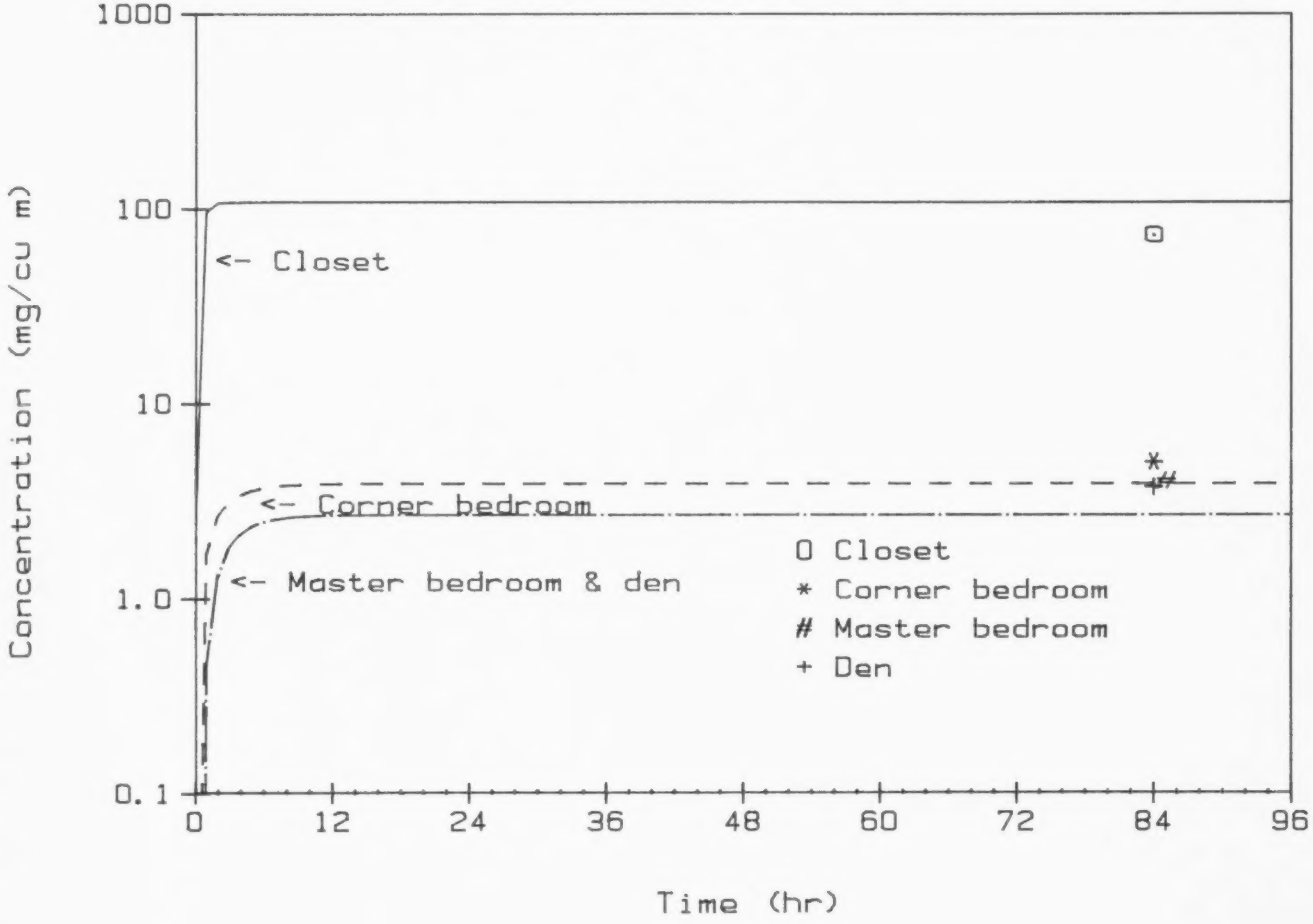


Figure 5-6. Model results with moderate sink.

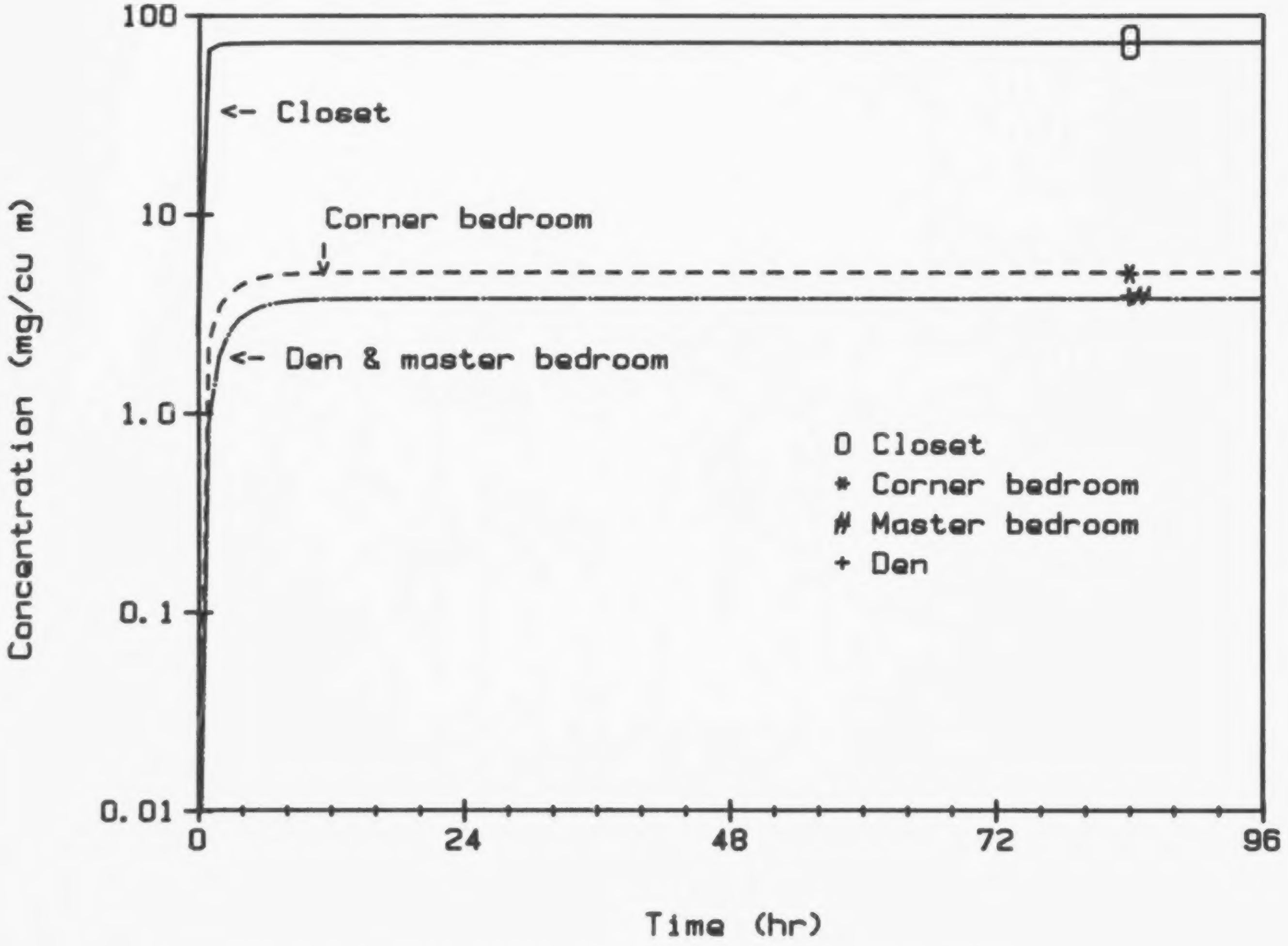


Figure 5-7. Final model results with measured flows.

The model calculations indicate that there is a large (4 to 8 m^3/h) air flow between the closet and the rest of the house. The air flow from the closet is divided between the corner bedroom, the hallway, and the master bedroom. This flow is higher than originally estimated.

CO_2 Experiments

CO_2 was injected into the closet to serve as a non-reactive tracer for calculating air flow from the closet. The CO_2 data have a much finer time resolution than do the p-dichlorobenzene data. Thus it is possible to compare model calculations with measurements for short time periods. The CO_2 is easier to model because there is no need for a sink term.

The decay of CO_2 from the closet and the rest of the house was modeled. The experimental data are shown in Figure 5-8.

The model input was the same as that used for the moth crystal final run. The model predictions are compared with the experimental data in Figure 5-9. Note that the model predicts the initial decay rate for all rooms quite well. However, the steady state value predicted by the model is much lower than that measured.

The reason for the model's failure to predict the steady state value is that two sources of CO_2 were not included in the model input: the pilot lights for both the gas furnace and the gas hot water heater.

Follow-up Experiments

Experiments were conducted to better define the air flows in the test house and to determine the reasonableness of the values used in the model. During these experiments the air handling system flows were measured. Flow visualization studies to determine the nature of the in-room and room-to-room mixing were conducted with neutral density balloons and with neutral density helium bubbles.

The air handling system measured flows are shown in Table 5-4, along with estimates used in the model. Note that the measured flows are close to those used in the model except for the front bedroom. The vents in the front bedroom were closed, accounting for the difference between measured and estimated flow.

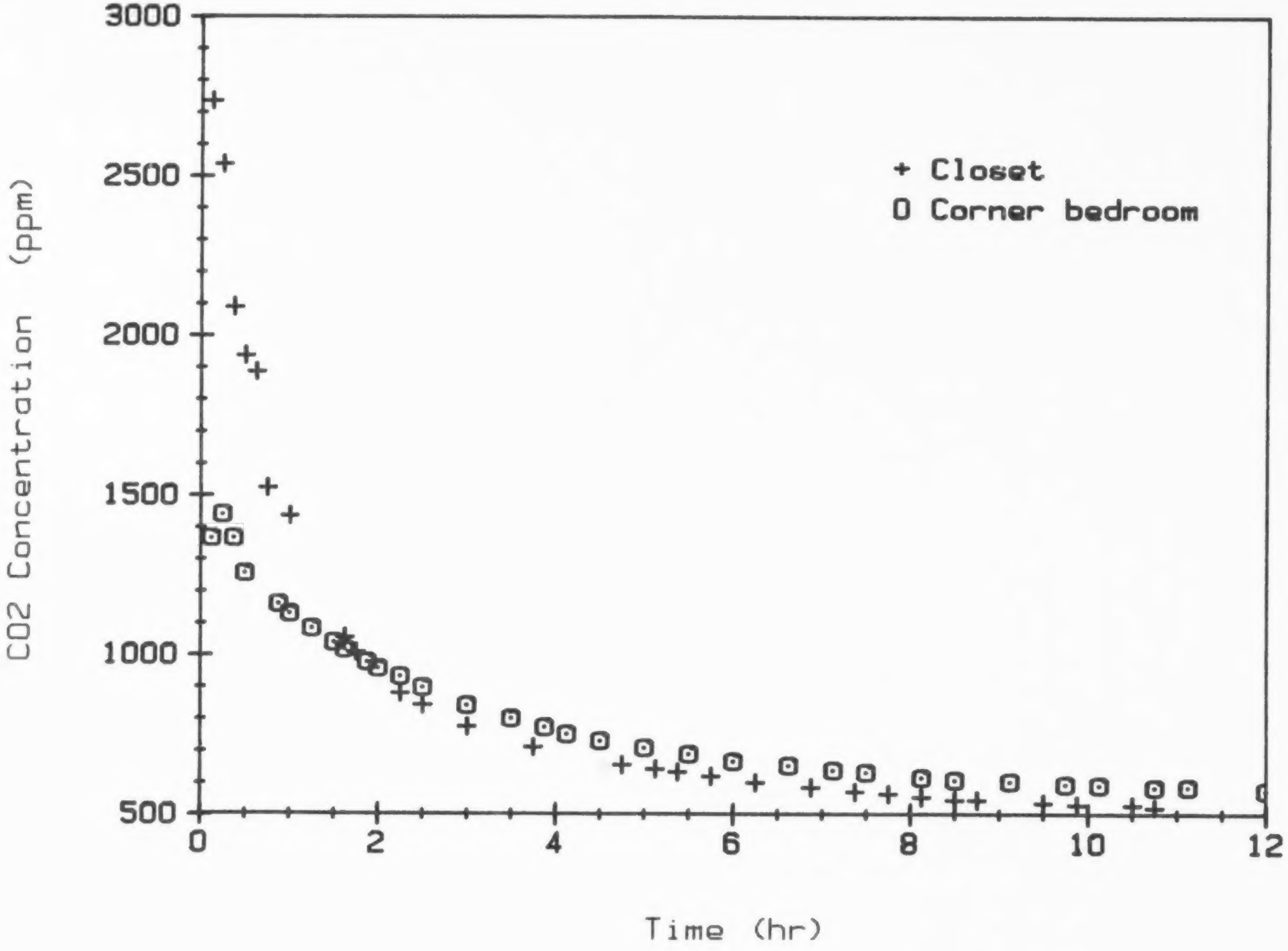


Figure 5-8. CO_2 test data for AEERL IAQ test house.

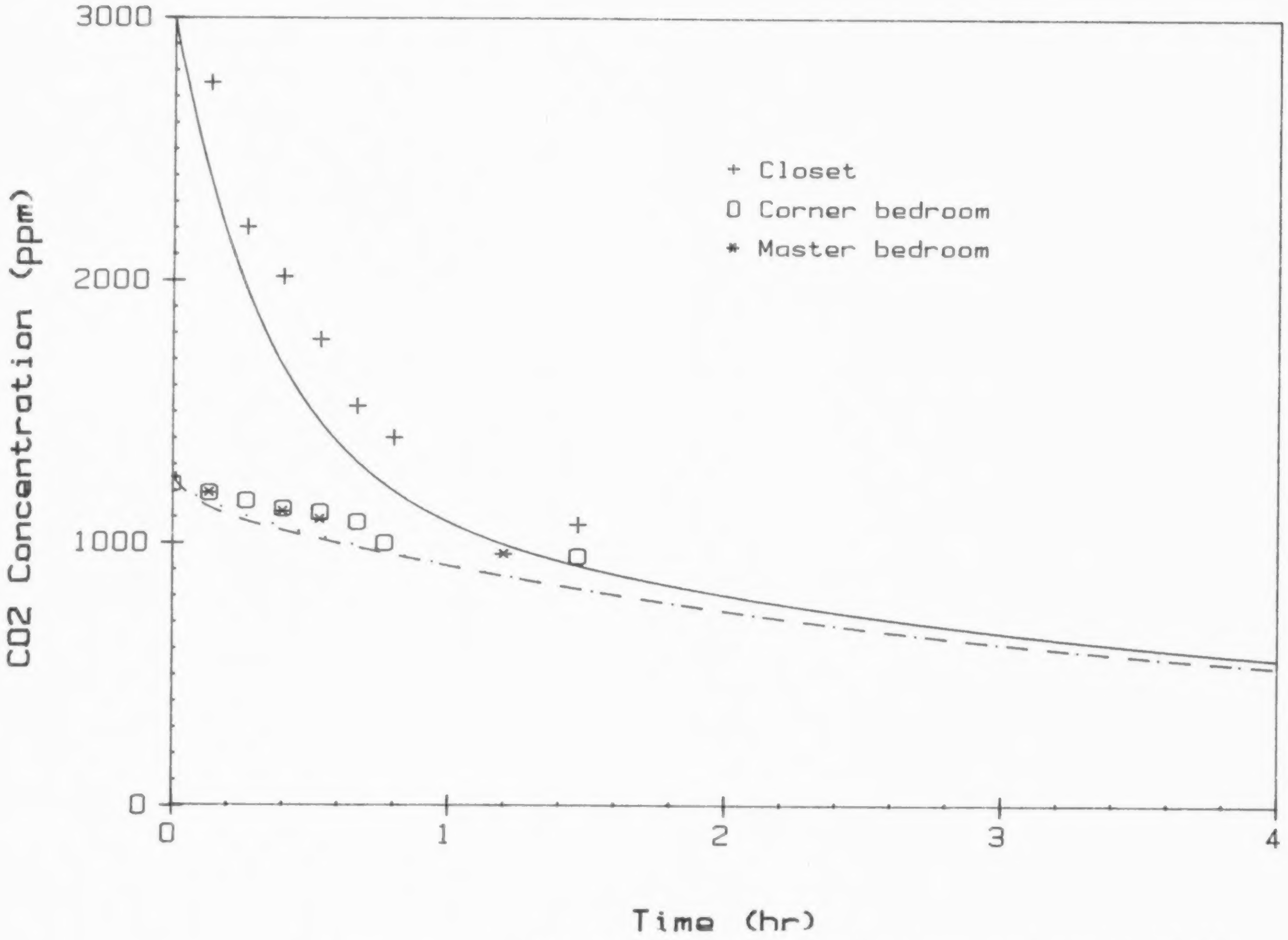


Figure 5-9. Comparison of model predictions and measured CO_2 data.

Table 5-4. Air handling system air flows in test house

Room	Measured Air flow m^3/h	Estimated Air flow m^3/h
Den	679	900
Middle bedroom	38	210
Corner bedroom	278	210
Master bedroom	280	210

The balloon and bubble experiments showed that, even with the air handling system on, considerable mixing existed between rooms. These experiments also indicated that there was a substantial air flow into and out of the closet. Finally the visualization studies indicated that there was flow between the closet and the hallway and between the closet and the master bedroom.

Hot-wire anemometer measurements of the air flow velocities through the cracks in the closet door showed that the air flow into and out of the closet was between 4 and 9 m^3/h. This is in excellent agreement with the air flows required by the model.

A final model run was conducted to determine the estimated p-dichlorobenzene concentrations in each room. The results of this run are shown in Table 5-3. The agreement between predictions and measurements improves slightly. However, because the rule of thumb estimates and the actual air handling system flows are quite close, there is no dramatic change in the model predictions.

Additional Modeling

An additional model run was made to determine the impact of the moth crystals on inhouse p-dichlorobenzene concentrations with normal (on/off) air handler system operation and to evaluate methods for reducing the in-house p-dichlorobenzene concentrations.

Normal Air Handler Operation

In a normal house the air handling system is on only part of the time. Thus the experimental data and model runs above are for an abnormal condition. The model can be used to estimate the p-dichlorobenze concentrations under normal operating conditions. These runs were based on the assumption that the air flows with the air handler on were the same as discussed above. When the air handler was off, however, it was assumed that there was no air exchange between the closet and the house. Air handler off interroom air flows were assumed to be 70 m^3/h between the den and the hall and 30 m^3/h between the hall and other rooms. The results of this model run are shown in Figure 5-10. (Recent experiments in the test house with the air handler off indicate that there is significant flow from the closet even with the door closed.

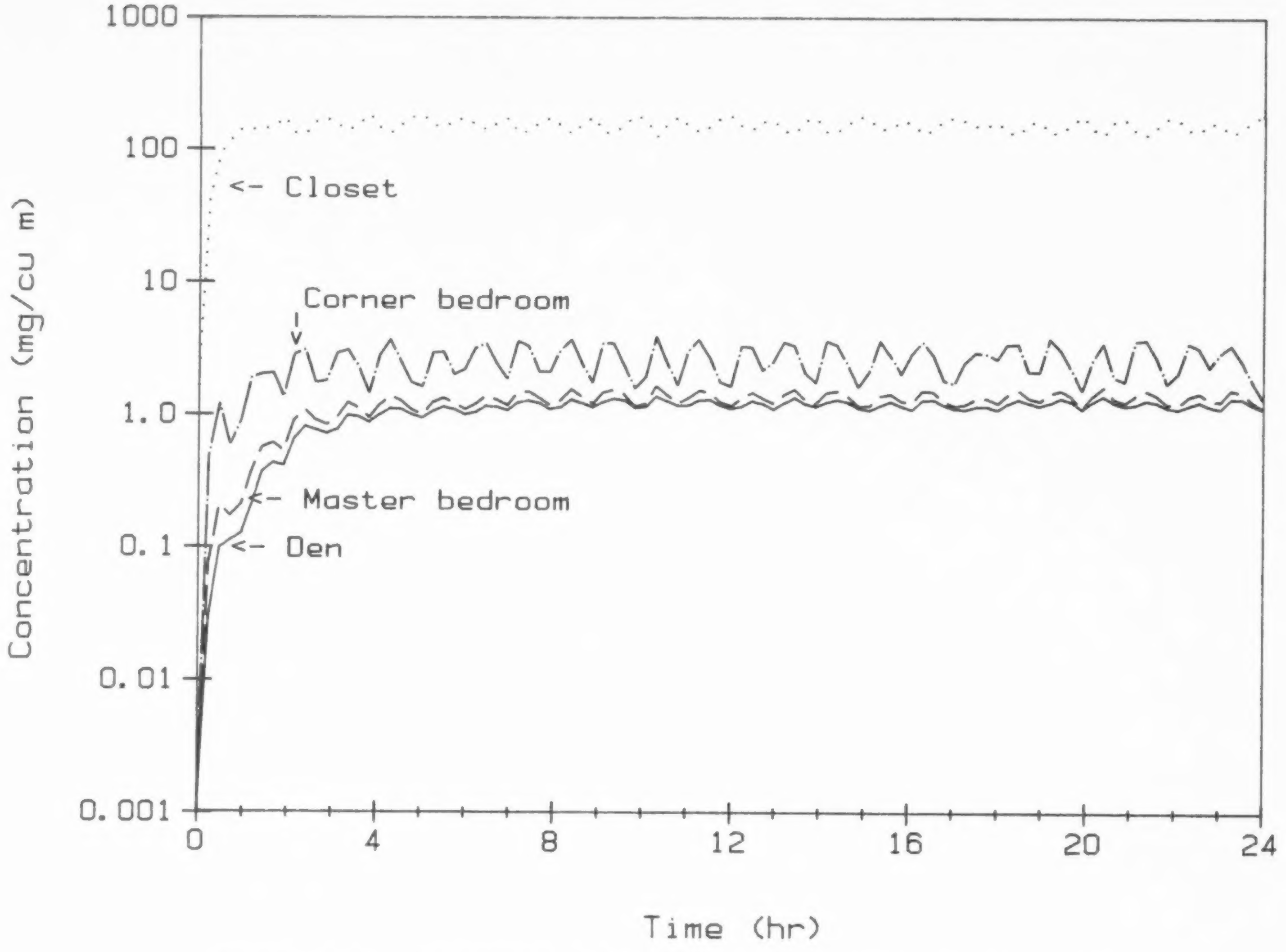


Figure 5-10. Predicted p-dichlorobenzene concentration with normal air handler operation.

The in-closet p-dichlorobenzene concentration increased slightly and the p-dichlorobenzene concentrations in the rest of the house dropped slightly. However, there were no major changes in the distribution of p-dichlorobenzene throughout the house.

Model Analysis of Mitigation Strategies

The model can be used to estimate the effectiveness of various strategies for reducing the p-dichlorobenzene concentrations in the house. The most obvious strategy is to remove the moth crystals. However, for this analysis it is assumed that the moth crystals must be used. It is also assumed that the p-dichlorobenzene concentration in the closet must not drop below 25 mg/m^3. Finally it is assumed that the maximum allowable concentration in the rest of the house is 0.5 mg/m^3. All runs will be for normal air handling system operation; i.e., air handler on 10% of the time.

The options analyzed are:

1. Reduce the source strength (i.e., use fewer moth crystals).
2. Seal the closet more effectively.
3. A combination of 1 and 2.

If the moth crystals are used at about 20% of the manufacturer's recommendation, the in-closet concentration can be maintained at the assumed value. However, as shown in Figure 5-11, the bedroom and den concentrations all exceed 0.5 mg/m^3.

The analysis of closet sealing assumes that the closet flow can be reduced to zero when the air handling system is off and to 0.1 m^3/h when the air handling system is on. The amount of moth crystal used is based on the manufacturer's recommendation. The results are shown in Figure 5-12. In this case the in-house concentrations are below 0.5 mg/m^3. Note that the den concentrations were below 0.1 mg/m^3 and are not shown in Figure 5-12.

The analysis of option 3 is shown in Figure 5-13. In this case the in-house concentrations are slightly greater than 0.01 mg/m^3 and the in-closet concentrations are above 25 mg/m^3.

In an actual situation the closet is opened periodically and then closed. This situation can be simulated by assuming that the closet is open about 1 minute an hour. During this minute the air flow into and out of the closet is assumed to be 18 m^3/h. The results of this simulation are shown in Figure 5-14.

Conclusions

The p-dichlorobenzene experiments show that emission factors from small chambers can be used with the model to provide useful estimates of the pollution concentrations found in a house for a single source. The model predictions based on rule of thumb factors (air exchange between rooms and the air handling system was estimated as 7 ACH) are in good agreement with the measurements, and the model predictions based on actual flow measurements are in excellent agreement with the data. The model runs demonstrate how the model can be used to guide experiments to discover causes of unexpected concentrations. The model can be used to evaluate different hypotheses as to causes and to discover the most reasonable hypothesis. For example, in the moth crystal example the possible explanations for the measured concentrations are the existence of a large sink for p-dichlorobenzene or considerable air flow from the closet. The model runs show that a large sink does not produce the measured room-to-room distribution of p-dichlorobenzene. The model runs show that air flow from the closet does produce the measured room-to-room distribution of p-dichlorobenzene. Subsequent measurements confirmed the existence of the air flows from the closet.

The model can also be used to quickly evaluate control options and to guide selection of appropriate control options.

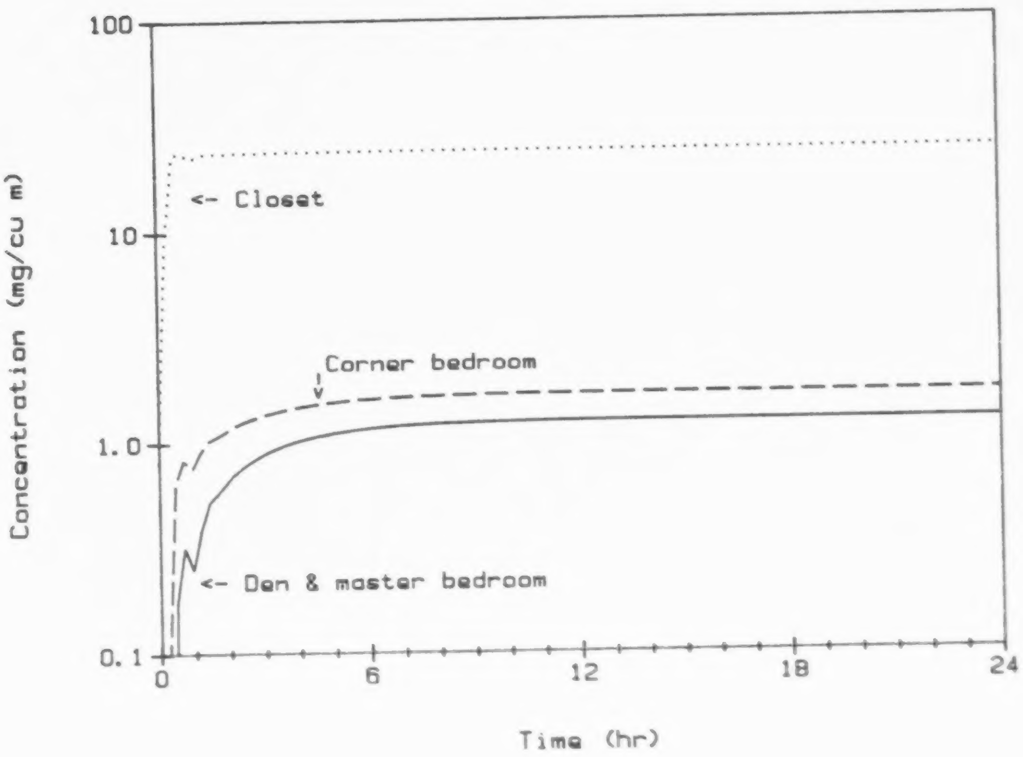


Figure 5-11. Effect of reduced moth crystal usage.

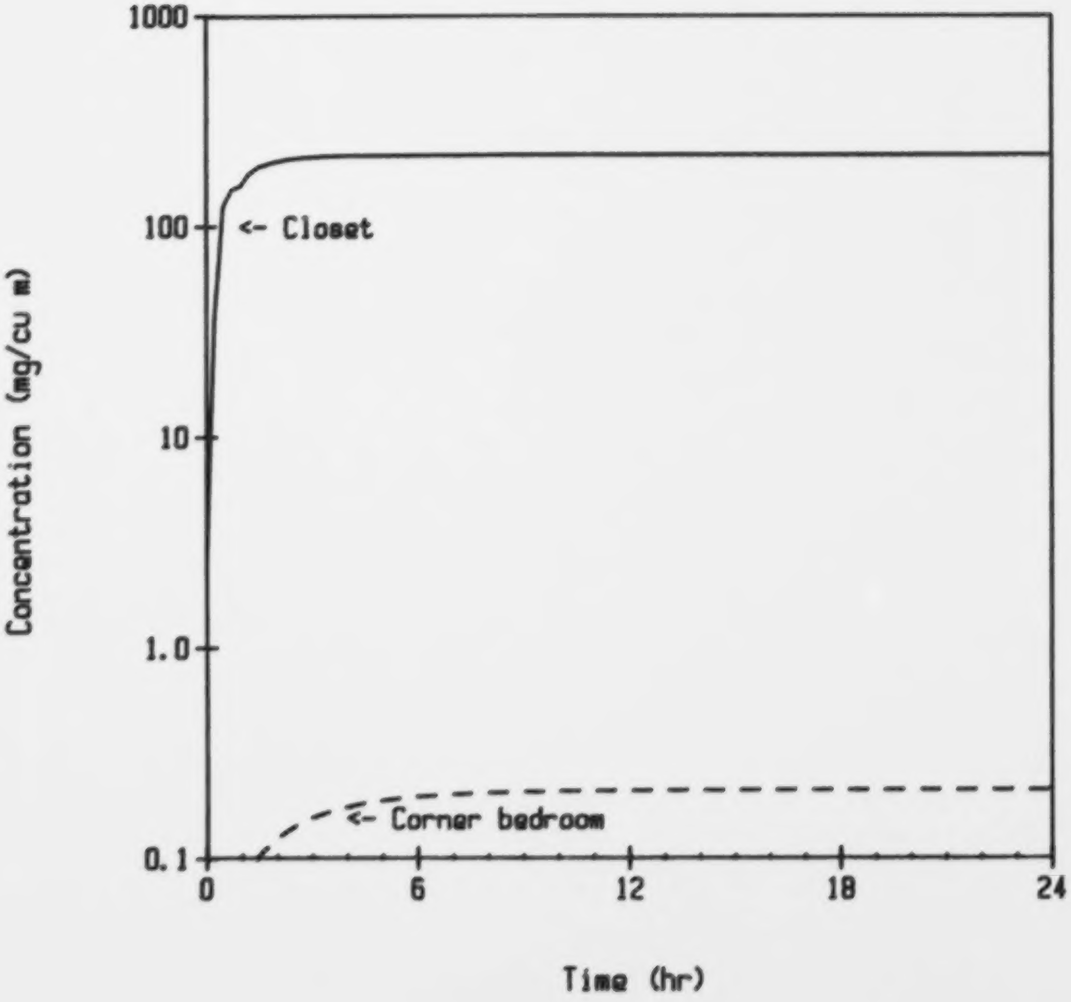


Figure 5-12. Effect of reduced flow from closet.

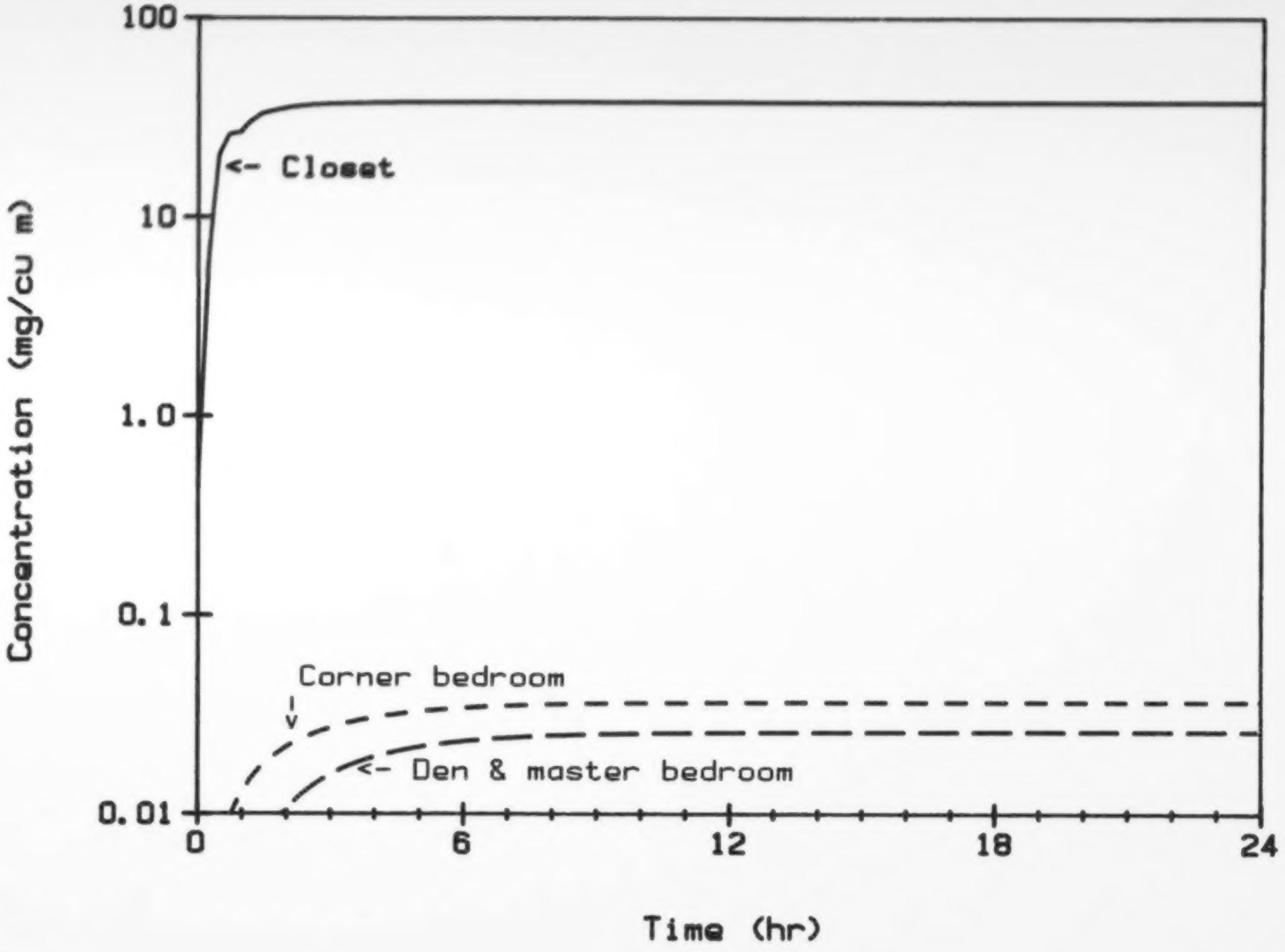


Figure 5-13. Effect of reduced flow and moth crystal usage.

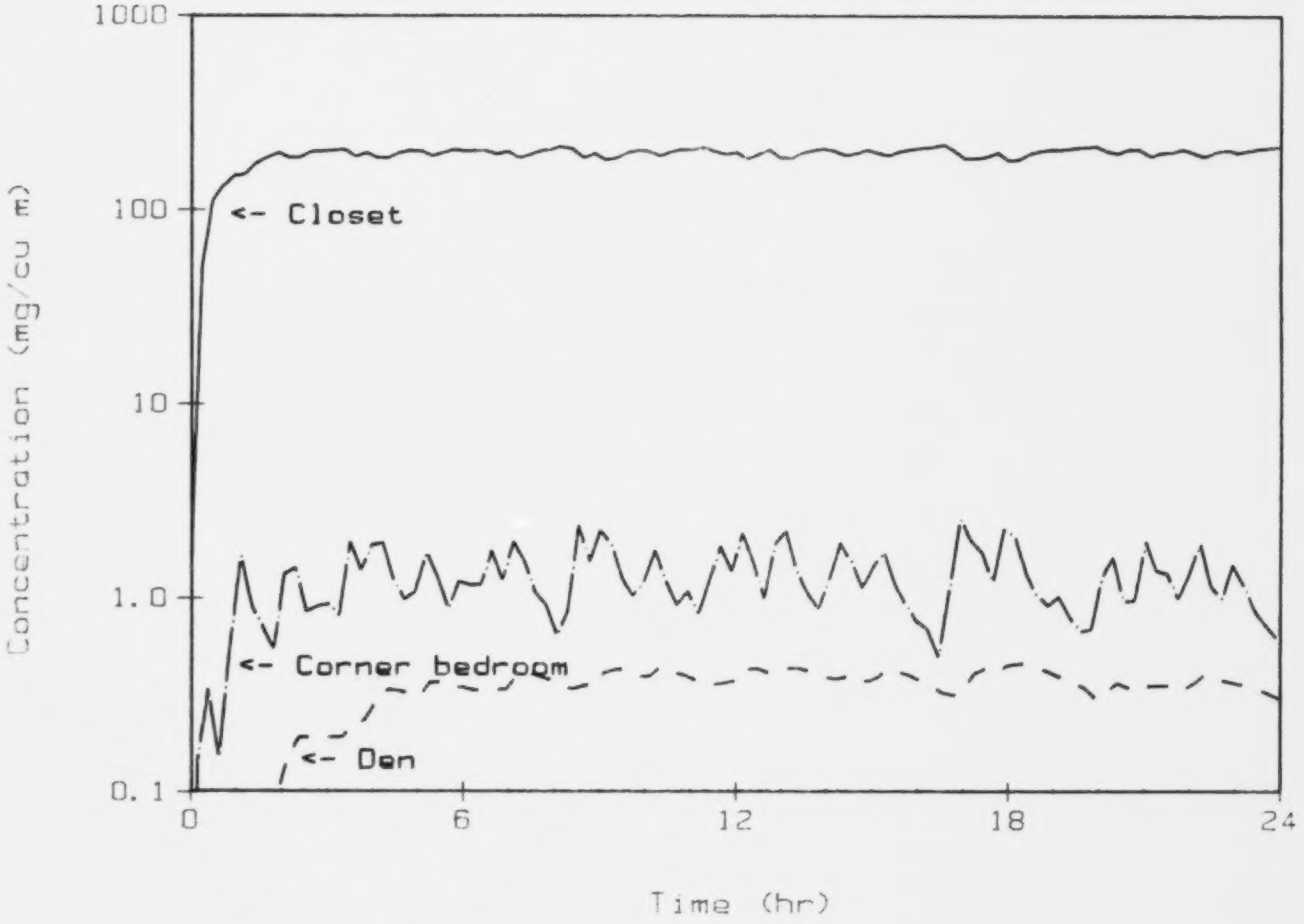


Figure 5-11. Effect of opening closet door 1 min an hour.

Reemitting Sink

Under some conditions sinks can become sources because the material collected in them is reemitted. An example of the effects of a reemitting sink on pollution concentrations indoors is shown in Figure 5-15. This figure shows the measured p-dichlorobenzene concentration in the test house after the moth crystals were removed from the closet. Note that the p-dichlorobenzene concentration does not rapidly drop to zero as would be expected once the source is removed. The p-dichlorobenzene concentration drops rapidly at first, and then drops very slowly, if at all, for several days.

Another data set for a reemitting sink is shown in Figure 5-16. These data are from a study of perchloroethylene concentrations in the test house. In this experiment a spike of perchloroethylene was released and the concentration measured as it decayed. The decay is initially much faster than expected due to dilution (evidence of a sink). The decay then becomes much slower than expected for pure dilution because the material collected in the sink is reemitted. The data indicate that perchloroethylene is reemitted when the in-room perchloroethylene concentration drops below about 15 $\mu g/m^3$.

The effect of the reemitting perchloroethylene sink on in-room perchloroethylene concentration is shown in Figure 5-17. In this case the perchloroethylene source is in the bedroom closet. The perchloroethylene emission rate, E_p, is:

$$E_p = 19000e^{-0.03t}Area_{cloth}$$

The reemission rate, R_p is:

$$R_p = \begin{cases} 35(C_{room} - 15)Area_{room}Mass_{sink} & \text{for } C_{room} \le 15\ \mu g/m^3 \\ 0 & \text{for } C_{room} > 15\ \mu g/m^3 \end{cases}$$

The effect of the reemitting sink is to reduce the initial concentration of perchloroethylene as material goes to the sink. Then when the perchloroethylene is reemitted, the sink maintains the perchloroethylene concentration at a relatively constant level until the sink is exhausted. The model predictions are in good agreement with the experimental data.

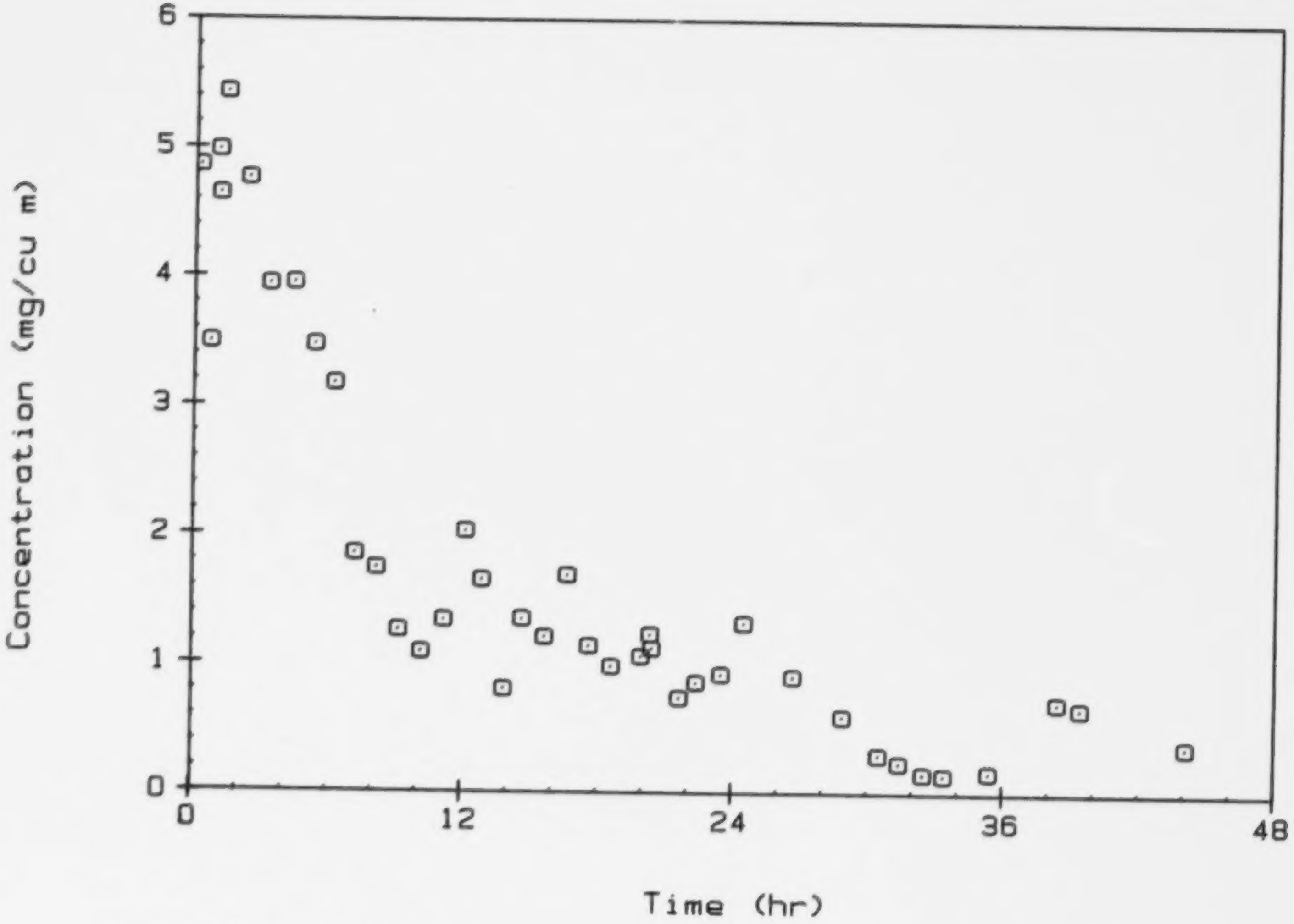


Figure 5-15. p-dichlorobenzene concentration after moth crystals were removed.

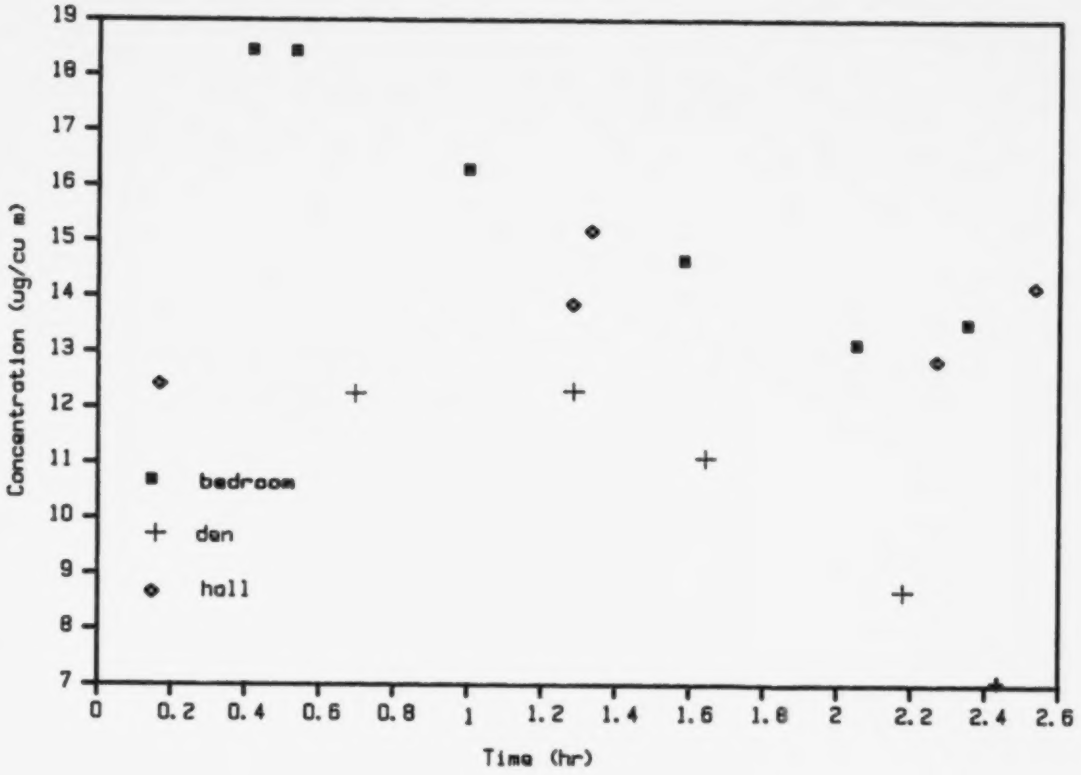


Figure 5-16. Data from perchloroethylene sink experiment.

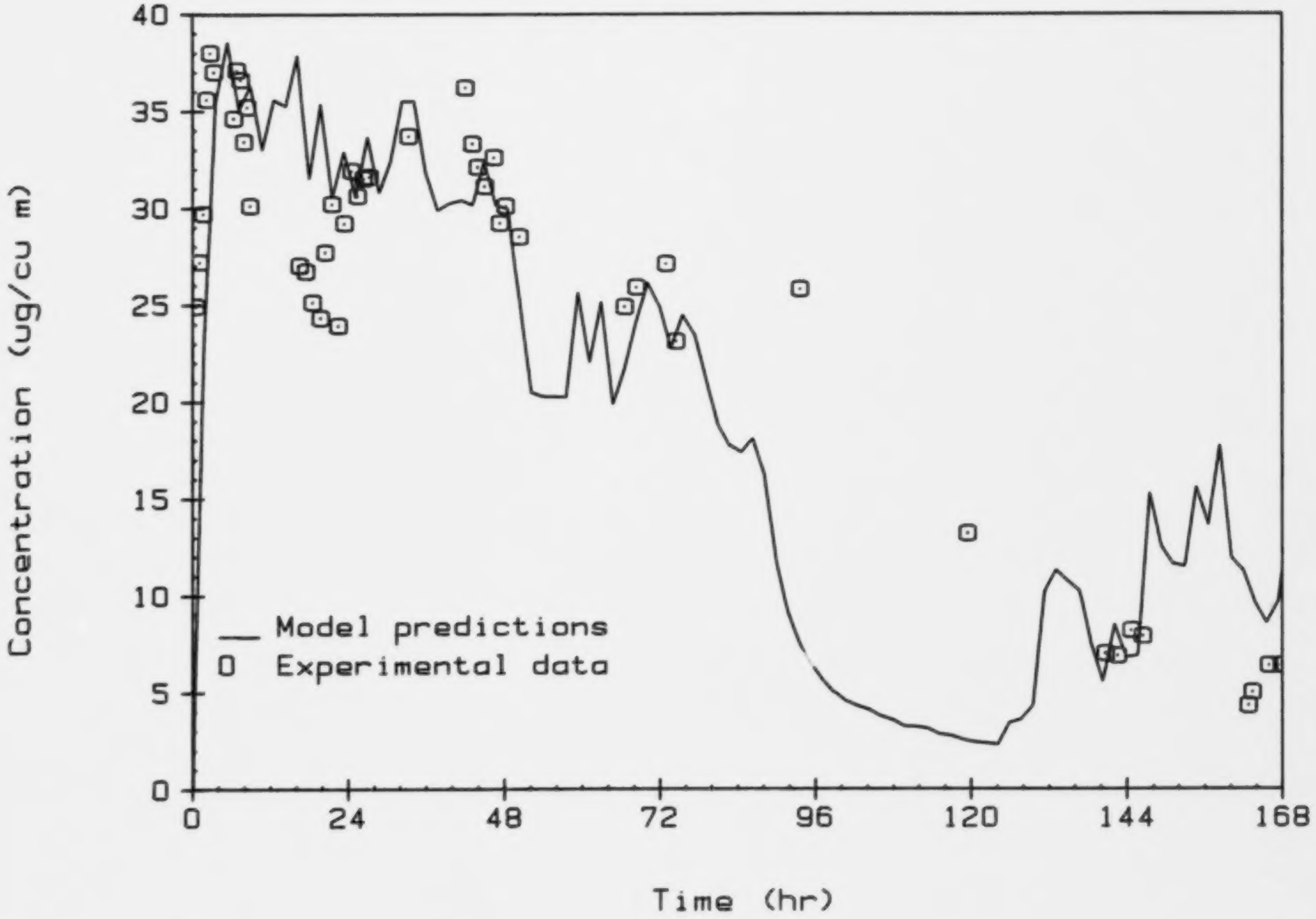


Figure 5-17. Model calculations and data for perchloroethylene.

SECTION 6.
HINTS ON USING THE MODEL

Efficient use of the model depends on the user's ability to recognize the important features that need to be modeled in detail and on the user's ability to simplify all aspects of the problem so that the model can deal with the problem. The suggestions in this section are based on the experience of working with the model in many situations.

Find the Source

Rooms with strong sources should be handled in some detail. The air flows into and out of these rooms play a major role in determining the quality of the air in the rest of the building. The moth crystal example clearly demonstrates the importance of flows out of the source room.

The important source characteristics should be determined and included in the model. The important source characteristics often depend on the time frame being modeled. For example, the initial short duration high emission rate of wet sources should be modeled if the time frame of the model (and the effects) is a few hours. If the time frame of the model were several days or weeks, the initial high emission rate might not be important, but the long term emission rate would be.

Source characterization can be done in small chambers if the experiments are well designed and if the experimental data are carefully analyzed.

The air flow characteristics of the source room can be estimated by a number of techniques. Direct measurement with low flow anemometers is one possibility. Another possibility is the use of tracer gases. CO_2 is a good tracer gas for many practical situations. The instruments are real time and not too expensive. A suggested way of using CO_2 is to add CO_2 to the room to increase the concentration to 1,000 to 2,000 ppm. Turn off the CO_2 and monitor the decrease in the source room and the increase in the rooms near the source room. Use the model to estimate flows necessary to give the measured results.

CO_2 can also be used as a tracer by adding a known constant amount of CO_2 to the room. The decay experiment is easier to run and model because there is no need to know the CO_2 generation rate.

Look for Sinks

Sinks are one of the most important factors in indoor air quality. Unfortunately not much is known about them. Sinks show up as consistently lower than predicted pollutant concentrations (see the moth crystal study for an example). When a sink is suspected, use a value for the sink constant of about 0.25 to

0.5. This will generally result in about 50% of the total material emitted going to the sink. A value much above 0.5 will generally result in too much material going to the sink.

Remember that many sinks are reversible and can become sources when a strong source is removed from the building. For example, the moth crystal study showed significant reversible sink effects when the moth crystals were removed from the test house.

References

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Press, W. H., B. P. Flannery, S. A. Teukolsky, and W. T. Vetterling (1987), Numerical Recipes The Art of Scientific Computing, Cambridge University Press, New York, NY.

Tichenor, B. A., J. E. Bunch, and M. A. Mason (1987) "Evaluation of Organic Emissions to the Indoor Environment via Small Chamber Testing," in Proceedings of the 1987 EPA/APCA Symposium on Measurement of Toxic and Related Air Pollutants, Research Triangle Park, NC May 1987.

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APPENDIX A
PROGRAM LISTING

```
DECLARE SUB dterror (deltat!)
REM Indoor air model version 1.2
QuickBasic 4.0 version
REM converted to use midpoint
method from Numerical Recipes
REM May 2 1988
REM faster than RK4
REM converted from QuickBasic
3.0  25 January 1988
REM converted to use RK4 April
20, 1988
DECLARE SUB sinkdef (sinkrate!,
remit!, reconc!)
DECLARE SUB massbal (deltat!,
second!, hr!, rs%, strength!(),
dmass!, concen!(), vambout!(),
jhv%, dmassout!, dsinkmass!)
DECLARE SUB sink1 (conc!, area!,
c!, xr, xc!, sink!, sinkmass!,
emiss!)
DECLARE SUB concroom (rs%,
concen!(), cout!(), second!,
hr!, jhv%, strength(), pt(),
sourcflag%(), sflag%)
DECLARE SUB house ()
DECLARE SUB ind87 ()
DECLARE SUB main ()
DECLARE SUB findmax (x!(),
xmax!, xmin!, npoints%)
DECLARE SUB plot (x!(), y!(),
npoints%, xmax!, xmin!, ymax!,
ymin!, room%)
DECLARE SUB getkey (y$, y%)
DECLARE SUB windmake (mon%, fc%,
bc%, ul%, ur%, ll%, lr%, f%)
DECLARE SUB getmove (curon%, y$,
jy%, row%, col%, cursor$,
blcur$)
DECLARE SUB movecursor (curon%,
row%, col%, dir$, upstep%,
downstep%, leftstep%,
rightstep%)
DECLARE SUB getdata (outans$,
y$, row%, col%)
DECLARE SUB cwind (fc%, bc%,
ur%, uc%, ll%, ar%)
DECLARE SUB form (mon%, fc%,
bc%, title$(), namtitle$,
numtitles%, valx!(), rowstart%,
rowfinish%, colstart%,
formtitle$)
DECLARE SUB plotem (time(),
pconc(), tmax%, nrooms%)
DECLARE SUB menu (fc%, bc%, ok$,
mainmen$(), startrow%, newrow%,
startcol%, nummtitle%,
menutitle$, choice%)
DECLARE SUB gconfig (mon$, mon%)

DECLARE SUB constsetup (cflag%,
deltain!, prntstep%, maxrooms%,
maxsources%, maxtimes%,
maxdays%, hrsday!, sinkst!)
DECLARE SUB init2 ()
DECLARE SUB menuin (a1$(), n%)
DECLARE SUB setup (menudat$(),
nchoices%, subitems%())
DECLARE SUB pollution (wax1!,
wax2!, wax3!, wax4!, wtime1!)
DECLARE SUB default (nrooms%)
DECLARE SUB setup1 (cflag%)
DECLARE SUB defpol ()
DECLARE SUB building (nrooms%,
vtotal!, new1%)
DECLARE SUB hvac (new1%,
fracton!, thvac!, ambair!, c0!,
opcyc!, pthvac!, volume!,
nrooms%, vin!(), vout!())
DECLARE SUB outside (concen!,
new1%)
DECLARE SUB sbalance (vin!(),
bal!(), nrooms%)
DECLARE SUB storedat (nrooms%,
pollutant%)
DECLARE SUB readdat (nrooms%,
pollutant%, filename$)
DECLARE SUB calculate ()
DECLARE SUB displ (time!(),
tmax%, concentration!(),
nrooms%, volume!())
DECLARE SUB lprnt (time!(),
tmax%, concentration!(),
nrooms%)
DECLARE SUB fileit (time!(),
tmax%, concentration!(),
nrooms%)
DECLARE SUB plotroom (x!(),
z!(), tmax%, nrooms%)
DECLARE SUB retriveit (time!(),
tmax%, concentration!())
DECLARE SUB ghvac (new1%,
fracton!, thvac!, ambair!,
opcyc!, volume!)
DECLARE SUB gasclean (pthvac!)
DECLARE SUB inter (roomnr%,
nrooms%, vin!(), vout!())
DECLARE SUB hvacsourc (j%)
DECLARE SUB buildingdef
(nrooms%, vtotal!, new1%)
DECLARE SUB distrib (nrooms%,
vtotal!, vambin!(), vambout!(),
vol!())
DECLARE SUB curstatus (rn%,
vot!, volume!, c0!, area!, n%,
sinks!(), nsink%, subitems%(),
sources$(), vin!(), vout!(),
hvacin!(), hvacout!(), ambin!(),
ambout!())
DECLARE SUB barmenu (oldcol%,
oldj%, title$(), nchoices%,
nitems%(), j%, row%)
DECLARE SUB rdef (volume!,
area!, floor!)
DECLARE SUB c0def (c0!)
DECLARE SUB sourcedef (so$, ss!,
xnsource!, room%, a!, B!, c!,
d!, floor!)
DECLARE SUB hflow (roomnr%,
vin!, vout!, case$)
DECLARE SUB ambflow (roomnr%,
vin!, vout!, case$)
DECLARE SUB formr (title$(),
numtitles%, valx!(), rowstart%,
rowfinish%, colstart%,
colfinish%, formtitle$)
DECLARE SUB cigdef (onecig!,
ss!, nsmokers%, cigon!, cigoff!)

DECLARE SUB kheatdef (ss!, btu!,
on1!, off1!, on2!, off2!, on3!,
off3!)
DECLARE SUB stovedef (ss!, btu!,
on1!, off1!, on2!, off2!, on3!,
off3!)
DECLARE SUB moth (ss!, gms!)
DECLARE SUB other2def (a!, B!,
c!, d!, ss!)
DECLARE SUB waxdef (ss!, floor!,
wtime!, wax1!, wax2!, wax3!,
wax4!, wax5!)
DECLARE SUB otherdef (ss!)
DECLARE SUB formw (title$(),
numtitles%, valx!(), rowstart%,
rowfinish%, colstart%,
colfinish%, formtitle$)
DECLARE SUB highlight (row%,
col%, title$)
DECLARE SUB subtitles (title$(),
n%(), j%, row%, col%)
DECLARE SUB getchr (y$)
DECLARE SUB udim (row%, col%,
title$)
DECLARE SUB wipesub (n%, col%)
DECLARE SUB gfile (filename$)
DECLARE SUB checkflow
(flowerror%)
DECLARE SUB calconc ()
DECLARE SUB zero (pthvac!,
pt!(), xmassout!, xmassemit!,
sinkmass!)
DECLARE SUB scale (pollutant%,
scale1!)
DECLARE SUB endit (endflag%,
day%, maxdays%, second!, hour!,
hrsday!, tmax%, t%, time1!)
DECLARE SUB hvac2 (fracton!,
ncycles%, jhv%, rs%, pthvac!,
pt!)
DECLARE SUB roomcal (rs%, jhv%,
second!, hr!, concen!(),
sourcflag%(), pt!(),
strength!(), xmassout!,
xmassemit!, sinkmass!, dtflag%)
DECLARE SUB update (t%, jhv%)
DECLARE SUB source (room%,
sourc!, second!, hr!, sflag%)
DECLARE SUB cigsourc (deltat!,
room%, hr!, sourc!)
DECLARE SUB massin (con!(),
nrooms%, volume!(), xmass!, t%)
DECLARE SUB inout (a$)
DECLARE SUB getrooms (nrooms%,
jnplot%, jroom%())
DECLARE SUB sroom ()
COMMON SHARED /c0/ erflag%
COMMON SHARED /c1/ pollutant$(),
pollutant%, pstrength()
COMMON SHARED /c2/ a(), B(),
c(), d(), calflag%, colr%()
COMMON SHARED /c3/ cigon(),
cigoff(), stoveon(), stoveoff(),
kheaton(), kheatoff(), cookon(),
cookoff(), hour, calstep%,
prntstep%
COMMON SHARED /c4/ maxrooms%,
maxsources%, maxtimes%,
maxdays%, hrsday, mon%, mon$,
sinkst, deltat
COMMON SHARED /c5/ fc%, bc%,
fracton, endflag, day%, second,
deltain, onecig, xaxismin%
COMMON SHARED /c6/ yaxismin%,
yaxismax%, xaxismax%, xstep%,
ystep%, pthvac
COMMON SHARED /c7/ mainmen$(),
inmenu$(), nmenu$(), vin(),
vout(), menudat()
COMMON SHARED /c9/ sources$(),
nsources%(), sinks(), nsinks%(),
nchoices%
COMMON SHARED /c8/ subitems%(),
volume(), c0(), area(), floor()
COMMON SHARED /c10/ vhvacin(),
vhvacout(), vambin(), vambout()
DIM ncig%(10), stobtu(10),
kheatbtu(10), gmoth(10),
time(740), pollutant$(10)
DIM cigon(10), cigoff(10),
stoveon(10, 3)
DIM stoveoff(10, 3), kheaton(10,
3), kheatoff(10, 3)
DIM a(10), B(10), c(10), d(10),
colr%(10)
DIM cookon(10, 3), cookoff(10,
3)
DIM wax1(10), wax2(10),
wax3(10), wax4(10), wax5(10)
DIM wtime1(10), xr(20), xc(20)
DIM snk1(20), snk2(20),
remis1!(20), remis2!(20)
CONST maxpoints = 720
CONST maxpollutants = 1
CONST maxsinks = 1
CONST ciglife = 10
REM end common
REM set up user functions
DEF fnhvon (f, ncycles%)
  IF ncycles% > 0 THEN
  j% = 1
  ELSE
  f1 = RND(1)
  IF f - f1 > 0 THEN j% = 1 ELSE
j% = 0
END IF
fnhvon = j%
END DEF
REM def fnsink2(a,b,c,d)
REM a is pollution concentration

REM b is area term
REM c is limit concentration
REM d is source strength
REM if a<c then s=a*0.001*b else
s=-1*d*a
REM fnsink2=s
REM end def
```

```
DEF fnstove (a, B, c, t)
IF a <> B THEN
h = t * 2.77778E-04 + hour
IF h >= a AND h <= B THEN s = 1
ELSE s = 0
fnstove = c * s
ELSE
s = 0
END IF
END DEF
DEF fnkero (a, B, c, t)
REM a is start time, b is finish
time, c is source strength
h = t * 2.77778E-04 + hour
IF a <> B THEN
 IF h >= a AND h <= B THEN s = 1
ELSE s = 0
 ELSE
 s = 0
END IF
 fnkero = c * s
END DEF
DEF fnoth (a, B)
fnoth = B
END DEF
DEF fnwax (time, area)
REM a is area and b is time in
hours
REM wax data based on Tichnor's
work
REM modified for perc
experiments
s = w1 * area * EXP(-w2 * time)
fnwax = s
END DEF
DEF fnsource2 (a, B, c, d, x)
fnsource2 = a + B * x + c *
EXP(d * x)
END DEF
DEFSTR M
DEFINT J, N
REM end user function area
REM error trapping
maxrooms% = 10
1 REM indoor air model
CALL gconfig(mon$, mon%)
CALL constsetup(-99, deltain,
prntstep%, maxrooms%,
maxsources%, maxtimes%,
maxdays%, hrsday, sinkst)
max% = maxsources%
maxr% = maxrooms%
maxa% = maxrooms%
REM $DYNAMIC
DIM xnsource(10, 6, 6),
sstrength(10, 6, 6)
REM $DYNAMIC
DIM mainmen$(8), inmenu$(8),
outmenu$(4), plotmenu$(4)
REM $DYNAMIC
DIM nlit%(maxa%, 25),
lit%(maxr%)
REM $DYNAMIC
DIM menudat$(maxrooms%,
maxrooms%),
subitems%(maxrooms%),
sources$(maxrooms%, maxrooms%),
nsources%(maxrooms%),
```

```
volume(maxrooms%)
REM $DYNAMIC
DIM title$(maxrooms%), x(10),
mtitle$(20), vin(maxrooms%,
maxrooms%, 2), vout(maxrooms%,
maxrooms%, 2),
vhvacin(maxrooms%, 2),
vhvacout(maxrooms%, 2),
pambin(10)
REM $DYNAMIC
DIM vambin(maxrooms%, 2),
vambout(maxrooms%, 2), nmenu(5)
REM $DYNAMIC
DIM rsinkmass!(maxrooms%),
concen(max%, maxa%),
sourcflag%(maxa%),
ssource(maxr%)
REM $DYNAMIC
DIM area(maxrooms%),
sinks(maxrooms%, maxsinks),
floor(maxrooms%)
REM $DYNAMIC
DIM pconc(maxpollutants,
maxrooms%, maxtimes%),
nsinks%(maxrooms%)
REM $DYNAMIC
DIM c0(maxrooms%), pstrength(10,
10), nsmokers%(10)
DIM emis1(maxrooms%),
emis2(maxrooms%),
emis3(maxrooms%),
emis4(maxrooms%)
REM main program
CALL init2
CALL menuin(inmenu$(), nmenu(2))

CALL menuin(outmenu$(),
nmenu(3))
CALL menuin(plotmenu$(),
nmenu(4))
CLS
FOR j% = 1 TO maxrooms%:
nsources%(j%) = maxsources%
nsinks%(j) = maxsinks: NEXT j%
CALL setup(menudat$(),
nchoices%, subitems%())
CALL pollution(w1, w2, w3, w4,
wt)'get pollutants and source
strengths
pollutant% = 1
pthvac = 1
roomnr% = 1
oldcol% = 1
oldj% = 1
d$ = ""
CALL default(nrooms%)
CALL house
CLS
SCREEN 0: COLOR fc%, bc%
WIDTH 80
CALL main
END
DEFINT E, R
DATA <E>nter
data...,<C>alculate,<O>utput
...., <P>lot
...,<S>etup,<Q>uit,end
DATA Specify <P>ollutant,Define
```

```
<B>uilding,Define <H>VAC,Define
<O>utside,Define <R>ooms
DATA <S>tore Data on Disk,<G>et
Data from Disk,<Q>uit,end
DATA   <D>isplay   results   on
CRT,<W>rite  results  to  file,
<P>rint results,<Q>uit,end
DATA <P>lot Results
DATA Plot <S>elected rooms,<G>et
Previous run,<Q>uit,end
D         A         T         A
room_number,definition,sources,
sinks,interconnections,done,end

DATA 1,2,3,4,5,6,7,8,9,10,end
DATA volume,initial conc,end
D         A         T         A
Cigs,K-heater,Unvented-stove,Mo
th crystals,Wax,Other,end
DATA walls,rugs,other,end
DATA  HVAC  1,HVAC  2,Outdoors
1,Outdoors 2,Other rooms,end
DATA end

DEFSNG E, R
SUB ambflow (roomnr%, vin, vout,
case$) STATIC
REDIM x(2), title$(2)
CALL  windmake(mon%,  fc%,  bc%,
10, 35, 16, 80, -1)
x(1) = vin: x(2) = vout
title$(1) = "Air from outdoor"
title$(2)  =  "Air  leaving  to
outdoor"
ftitle$ = "[Define ambient flow
case ]" + case$
CALL formw(title$(), 2, x(), 10,
11, 41, 75, ftitle$)
vin = x(1): vout = x(2)
IF v$ <> "" THEN vout = VAL(v$)
CALL cwind(fc%, bc%, 10, 35, 16,
80)
END SUB

SUB  barmenu  (oldcol%,  oldj%,
title$(), nchoices%, nitems%(),
cj%, crow%) STATIC
COLOR fc%, bc%
row% = 1: col% = 1
FOR j% = 1 TO nchoices%
LOCATE   row%,   col%:   PRINT
title$(j%, 0);
col% = 5 + LEN(title$(j%, 0)) +
col%
NEXT j%
row% = 1: col% = oldcol%: j% =
oldj%
CALL   highlight(row%,   col%,
title$(j%, 0))
CALL    subtitles(title$(),
nitems%(), j%, row%, col%)
y$ = " "
WHILE ASC(y$) <> 13
CALL getchr(y$)
IF ASC(y$) = 27 THEN
  j% = nchoices%
  y$ = CHR$(13)
ELSE
IF LEN(y$) > 1 THEN
 y$ = RIGHT$(y$, 1)
 CALL    udim(row%,    col%,
title$(j%, row% - 1))
 jj = ASC(y$)
 SELECT CASE jj
  CASE 80 'down
    IF row% <= nitems%(j%) THEN
row% = row% + 1
    CALL highlight(row%, col%,
title$(j%, row% - 1))
  CASE 72 'up
   IF row% > 2 THEN row% = row%
- 1
   CALL  highlight(row%,  col%,
title$(j%, row% - 1))
 CASE 77 'right
     IF j% < nchoices% THEN
     CALL  wipesub(nitems%(j%),
col%)
    col%   =   col%   +   5   +
LEN(title$(j%,  0)):  oldcol%  =
col%
    row% = 1
    j% = j% + 1: oldj% = j%
    CALL   highlight(1,   col%,
title$(j%, 0))
    CALL    subtitles(title$(),
nitems%(), j%, row%, col%)
    ELSE
    CALL   highlight(1,   col%,
title$(j%, 0))
    END IF
CASE 75 'left
   IF j% > 1 THEN
   CALL    wipesub(nitems%(j%),
col%)
   j% = j% - 1: oldj% = j%
   col%   =   col%   -   5   -
LEN(title$(j%,  0)):  oldcol%  =
col%
   row% = 1
   CALL   highlight(1,   col%,
title$(j%, 0))
   CALL   subtitles(title$(),
nitems%(), j%, row%, col%)
   ELSE
    CALL   highlight(1,   col%,
title$(j%, 0))
  END IF
CASE ELSE
 END SELECT
 END IF
END IF
WEND
   CALL    wipesub(nitems%(j%),
col%)
   CALL    wipesub(nitems%(j%),
col%)
 CALL    udim(row%,    col%,
title$(j%, row% - 1))
   cj% = j%: crow% = row%
END SUB

SUB building (nrooms%, vtotal,
new1%) STATIC
 SHARED  vambin(),  vambout(),
volume()
```

```
  CALL buildingdef(nrooms%,
vtotal, new1%)
  CALL distrib(nrooms%, vtotal,
vambin(), vambout(), volume())
END SUB

SUB buildingdef (nrooms%,
vtotal, new1%) STATIC
 REDIM title$(10), x(20)
  new1% = 1
  y% = -1
  WHILE y% = -1
   y% = 0
   CLS
   title$(1) = "Number of rooms
Max = " + STR$(maxrooms%)
   x(1) = nrooms%
    title$(2) = "Total
ventilation rate air changes/hr"

   x(2) = vtotal
   CALL form(mon%, fc%, bc%,
title$(), "Item", 2, x(), 12,
13, 10, "Building definition")
   nrooms% = INT(x(1)): vtotal =
x(2)
   IF nrooms% > maxrooms% THEN
    COLOR fc%, bc%
    PRINT
    PRINT
    PRINT "ERROR ERROR. Number
of rooms exceeds maximum of ";
maxrooms%
    PRINT "Press any key to
reenter data"
    CALL getkey(y$, y%)
    y% = -1
   END IF
   COLOR fc%, bc%
   CLS
   COLOR fc%, bc%
 WEND
END SUB

DEFINT E, R
SUB c0def (c0) STATIC
REDIM title$(2), x(2)
CALL windmake(mon%, fc%, bc%,
10, 40, 15, 75, -1)
LOCATE 9, 41: PRINT "[Define
initial conc] ";
title$(1) = "Initial
concentration"
x(1) = c0
CALL formw(title$(), 1, x(), 10,
10, 41, 75, "[Initial conc]")
CALL cwind(fc%, bc%, 10, 40, 15,
75)
c0 = x(1)
END SUB

DEFSNG R
SUB calconc STATIC
SHARED w1, w2, w3, w4, w5, wt
SHARED wax1(), wax2(), wax3(),
wax4(), wax5(), wtime1()
SHARED sstrength(), xnsource(),
sinkmass
```

```
SHARED time(), tmax%, nrooms%,
conc, ventotal, thvac, ambair,
pollutant%, pstrength()
SHARED fracton, partcont,
orgcont, pconc(), concen(),
pollutant$()
SHARED sources$(), nsources%(),
sinks(), nsinks%(), volume(),
c0(), xmassout, xmassemit
SHARED area(), floor(), vin(),
vout(), vhvacin(), vhvacout(),
vambin(), vambout()
SHARED ncig%(), stobtu(),
kheatbtu(), gmoth(), scale1,
sourcflag%(), nlit%(), lit%()
SHARED xc(), xr()
REDIM deltaconc(maxpollutants,
nrooms%), concen(maxpollutants,
nrooms%)
REDIM pambin(nrooms%)
REDIM sourcflag%(nrooms%),
fhvac(nrooms%, nrooms%)
REDIM nlit%(nrooms%, 25),
lit%(nrooms%), pt(nrooms%),
strength(nrooms%)
DEFINT J, N, R
tmax% = maxpoints
CALL zero(pthvac, pt(),
xmassout, xmassemit, sinkmass)
   FOR room% = 1 TO nrooms%
   IF concen(1, room%) < 1E-08
THEN concen(1, room%) = 1E-08
 NEXT room%
IF scale1 <= 0 THEN scale1 = .01

time(0) = 0
tmax% = 1
deltaflag% = 0
CALL scale(pollutant%, scale1)
deltat = deltain
 az$ = STRING$(76, " ")
 lenaz% = 76
 endflag = 0
CLS
ncycles% = 0
LOCATE 1, 1: PRINT "ROOM
                 CONCENTRATION
mg/m3";
LOCATE 1, 71: PRINT "> ";
scale1;
r% = 1: FOR r% = 0 TO nrooms%:
LOCATE r% + 2, 1: PRINT r%; :
NEXT r%
t% = 1
LOCATE 25, 2: PRINT "Press esc
to abort calculations";
REM start calculation loop
psink = 0
hrsec = 3600!
prntcount% = prntstep%
   FOR jr% = 1 TO nrooms%:
   strength(jr%) = 0
   FOR js% = 1 TO 5: FOR jp% = 1
TO 6:
   strength(jr%) = xnsource(jr%,
js%, jp%) * sstrength(jr%, js%,
jp%) + strength(jr%)
   NEXT jp%: NEXT js%: NEXT jr%
```

```
FOR day% = 1 TO maxdays%
hour = 0
 IF endflag = -1 THEN EXIT
FOR'exit if esc pressed
WHILE hour < hrsday
    LOCATE 22, 2: PRINT "Time:
Day "; day%; " hour "; hour;
    LOCATE 24, 2: PRINT "+ shows
source on in room   - shows no
source in room.";
    FOR j% = 0 TO nrooms%:
nlit%(j%, hour) = 0: NEXT j%
    jhv = 1
    second = 0
    timon = 0
    tfract = 0
    WHILE second < hrsec
     z$ = INKEY$:
     IF z$ <> "" THEN
     IF ASC(z$) = 27 THEN
      CALL endit(endflag, day%,
maxdays%, second, hour, hrsday,
tmax%, t%, timel)
     END IF
     END IF
     prntcount% = prntcount% +
1: deltaflag% = -1
       IF tfract <= fracton THEN

     IF fracton < 1 THEN
      IF tfract > fracton THEN
ncycles% = -10
      IF ncycles% <= 0 THEN
         CALL hvac2(fracton,
ncycles%, jhv, rs%, pthvac,
pt(0))
      ELSE
       ncycles% = ncycles% - 1
      END IF
     IF jhv = 1 THEN
      timon = timon + deltat
      tfract = timon / hrsec
     END IF
       END IF
       ELSE
     jhv = 0
      END IF
      IF hour > hrsday THEN hour
= hrsday
      hr = second * 2.77778E-04
+ hour
      CALL roomcal(rs%, jhv,
second, hr, concen(),
sourcflag%(), pt(), strength(),
xmassout, xmassemit, sinkmass,
dtflag%)
       CALL massbal(deltat,
second, hr, rs%, strength(),
dmass, concen(), vambout(), jhv,
dmassout, dsinkmass)
      IF dtflag% = -1 THEN
      CALL dterror(deltat)
      EXIT SUB
      END IF
      xmassemit = xmassemit +
dmass
      xmassout = xmassout +
dmassout
```

```
      sinkmass = dsinkmass
      IF prntcount% >= prntstep%
THEN
   IF t% < maxtimes% THEN
time(t%) = second + 3600 * (hour
+ 24 * (day% - 1)) ELSE t% =
maxtimes%
   deltatflag% = -1
   CALL update(t%, jhv)
   t% = t% + 1: prntcount% = 0
      END IF
     second = second + deltat
  WEND
  hour = hour + 1
  IF hour >= 23 THEN
     deltat = deltain
  END IF
WEND
NEXT day%
 time(t%) = second + 3600 *
((hour - 1) + 24 * (day% - 2))
 CALL update(t%, jhv)
tmax% = t%
END SUB

REM $STATIC
DEFSNG E, R
SUB calculate STATIC
SHARED time(), tmax%, nrooms%,
conc, ventotal, thvac, ambair,
fracton, partcont
SHARED orgcont, sources$(),
nsources%(), sinks(), nsinks%(),
volume()
SHARED c0(), area(), floor(),
vin(), vout(), vhvacin(),
vhvacout(), vambin()
SHARED vambout(), pconc()
REM SHARED ncig%(), stobtu(),
kheatbtu(), gmoth(), xnsource(),
sstrength()
REM first check flow
flowerror% = 0
CALL checkflow(flowerror%)
IF flowerror% = 0 THEN
CALL calconc
END IF
END SUB

REM $DYNAMIC
SUB checkflow (flowerror%)
STATIC
SHARED ventotal, thvac,
vambout(), vambin(), vhvacin(),
vhvacout()
SHARED nrooms%, volume()
DEFINT E, J
errortotal = 1
CLS
totalambout = 0
totalambin = 0
totalhvin = 0: totalhvout = 0
bvolume = 0
jhv = 1
FOR j% = 1 TO nrooms%
 totalambout = totalambout +
vambout(j%, jhv)
 totalambin = totalambin +
vambin(j%, jhv)
 totalhvin = totalhvin +
vhvacin(j%, jhv)
 totalhvout = totalhvout +
vhvacout(j%, jhv)
 bvolume = bvolume + volume(j%)
NEXT j%
totven = bvolume * ventotal
tothvac = bvolume * thvac
balancehvac = totalhvin -
totalhvout
balanceamb = totalambin -
totalambout
IF totalhvin > 0 THEN
   IF ABS(balancehvac /
totalhvin) > .00001 THEN ehvac =
1 ELSE ehvac = 0
  IF ABS(tothvac - totalhvin) /
totalhvin > .00001 THEN etotalh
= 1 ELSE etotalh = 0
 ELSE
  ehvac = 0
   etotalh = 0
END IF
IF totalambin > 0 THEN
IF ABS(balanceamb / totalambin)
> .00001 THEN eamb = 1 ELSE eamb
= 0
IF ABS(totven - totalambin) /
totalambin > .00001 THEN etotala
= 1 ELSE etotala = 0
ELSE
eamb = 0
etotala = 0
END IF
errortotal = ehvac + eamb +
etotala + etotalh
IF errortotal > 0 THEN
   IF ehvac = 1 THEN
     PRINT "Error.  HVAC flows
do not balance "
      PRINT balancehvac,
totalhvin, totalhvout
    PRINT "DO you want to
continue";
    y$ = INPUT$(1)
    IF y$ = "Y" THEN errtotal =
0 ELSE STOP

END IF
   IF eamb = 1 THEN
     PRINT "ERROR Ambient flows
to not balance."
   END IF
   IF etotala = 1 THEN
     CLS
     PRINT "ERROR. Ambient flows
into rooms does not agree"
     PRINT "with total ambient
air flow for building."
     PRINT "Do you want to use
room totals Y or N?"
     y$ = INPUT$(1)
    IF INSTR("YyNn", y$) < 3
THEN
      totven = totalambin
      tven = totven / bvolume
      errortotal = 0
    END IF
 END IF
  IF etotalh = 1 THEN
    errortotal = etotalh
    PRINT "ERROR. HVAC flows
into rooms does not agree with"
    PRINT "TOTAL hvac air flow
for building."
    PRINT "Do you want to use
room totals Y or N?"
    y$ = " "
     y$ = INPUT$(1)
    IF INSTR("YyNn", y$) < 3
THEN
      tothvac = totalhvin
      thvac = tothvac / bvolume
      errortotal = 0
     END IF
   END IF
  END IF
 IF errortotal <> 0 THEN
flowerror% = 1 ELSE flowerror% =
0
END SUB

DEFSNG E
SUB cigdef (onecig, ss,
nsmokers%, cigon, cigoff) STATIC

REDIM x(5), title$(5)
CALL windmake(mon%, fc%, bc%,
10, 40, 17, 75, -1)
LOCATE 9, 41: PRINT "[Define cig
source strength] ";
title$(1) = "Single Cig mg "
title$(2) = "Nr. cigs/hr "
title$(3) = "Nr. smokers"
title$(4) = "Start time"
title$(5) = "Stop time"
x(1) = onecig
x(2) = ss
x(3) = nsmokers%
x(4) = cigon
x(5) = cigoff
CALL formw(title$(), 5, x(), 10,
14, 41, 75, "[Define cig]")
CALL cwind(fc%, bc%, 9, 40, 16,
75)
ss = x(2): onecig = x(1): cigon
= x(4): cigoff = x(5)
nsmokers% = x(3)
END SUB

DEFINT E, R
SUB cigsourc (deltat, room%, hr,
sourc) STATIC
SHARED cigon(), cigoff(),
sstrength(), nlit%(), lit%(),
xnsource()
SHARED hour, pollutant%,
nsmokers%()
ncigs = xnsource(room%, 1,
pollutant%)
onecig = sstrength(room%, 1,
pollutant%)
sourc = 0
c = ncigs * onecig
pstep = deltat * 2.77778E-04
```

```
  IF c > 0 THEN
    IF hr >= cigon(room%) AND hr
<= cigoff(room%) THEN
      IF lit%(room%) > 0 THEN
     sourc = onecig / ciglife /
60 * nsmokers%(room%)
     lit%(room%) = lit%(room%) -
deltat
      ELSE
     lit%(room%) = 0
     IF nlit%(room%, hour) >=
ncigs THEN pl = EXP(-8 -
(nlit%(room%, hour) - ncigs))
ELSE pl = ncigs * pstep * ncigs
* 1.53
     IF (1 - RND(1)) < pl THEN
       sourc = onecig / ciglife
/ 60 * nsmokers%(room%)
       nlit%(room%, hour) =
nlit%(room%, hour) + 1
       lit%(room%) = ciglife *
60
     ELSE
       sourc = 0
       END IF
     END IF
   END IF
  END IF
END SUB

REM $STATIC
DEFSNG E
SUB concroom (rs%, cin(),
cout(), second, hr, jhv%,
strength(), pt(), sourcflag%(),
sflag%) STATIC
SHARED nrooms%, lit%(), nlit%(),
rsinkmass!(), remis1!()
SHARED ssource(), xnsource(),
pambin(), xr(), xc(), snk1()
SHARED sources$(), nsources%(),
sinks(), nsinks%(), volume(),
c0()
SHARED area(), floor(), vin(),
vout(), vhvacin(), vhvacout(),
vambin(), vambout()
SHARED ncig%(), stobtu(),
kheatbtu(), gmoth(), pconc(),
pollutant%
SHARED emis1!()
REDIM cout(1, nrooms%)
emis! = 0
FOR room% = rs% TO nrooms%
   pin = pambin(room%): pout =
cin(1, room%) * vambout(room%,
jhv) * 2.77778E-04
 FOR j% = rs% TO nrooms%
     IF j% <> room% THEN
      pin = pin + cin(1, j%) *
vin(room%, j%, jhv) *
2.77778E-04 * pt(j%):
      pout = pout + cin(1,
room%) * vout(room%, j%, jhv) *
2.77778E-04
     END IF
    NEXT j%
    psink = 0: emiss! = 0
   IF sinks(room%, 1) > 0 THEN
```

```
   CALL sink1(cin(1, room%),
area(room%), sinks(room%, 1),
xr(room%), xc(room%), sink,
rsinkmass!(room%), emiss!)
   psink = sink * 2.77778E-04
   snk1(room%) = psink
   ELSE
   psink = 0
  END IF
  pout = pout + psink: sourc =
0: sjs = 0:
   IF strength(room%) > 0 THEN
CALL source(room%, sourc,
second, hr, sflag%) ELSE sourc =
0
   emis1!(room%) = sourc
   remis1!(room%) = emiss!
   sourc = sourc + emiss!
   cout(1, room%) = (pin - pout
+ sourc * 2.77778E-04) /
volume(room%)
    IF sourc > 0 THEN
sourcflag%(room%) = 1 ELSE
sourcflag%(room%) = 0
 NEXT room%
END SUB

REM $DYNAMIC
DEFINT E
SUB constsetup (cflag%, deltain,
prntstep%, maxrooms%,
maxsources%, maxtimes%,
maxdays%, hrsday, sinkst) STATIC

IF cflag% = -99 THEN
maxrooms% = 10
maxsources% = 6
maxtimes% = 740
maxdays% = 1
hrsday = 24
deltain = 5
prntstep% = 30
END IF
END SUB

DEFSNG E, R
SUB curstatus (rn%, vot, volume,
c0, area, n%, sinks(), nsink%,
subitems%(), sources$(), vin(),
vout(), hvacin(), hvacout(),
ambin(), ambout()) STATIC
SHARED xnsource(), sstrength(),
pollutant%, pollutant$()
REDIM tvin(5), tvout(5),
balance(5)
SCREEN 0
fm$ = "##.#"
REM call
cwind(fc%,bc%,11,20,17,60)
REM call
cwind(fc%,bc%,15,5,24,80)
COLOR fc%, bc%
CALL cwind(fc%, bc%, 24, 1, 25,
80)
LOCATE 24, 10: PRINT "Pollutant
being modeled ";
pollutant$(pollutant%);
LOCATE 25, 1: PRINT "Use arrow
```

```
keys  to  move  cursor.   Press
<ENTER>  to  select,  ESC  to
return.";
CALL windmake(mon%, fc%, bc%, 9,
4, 16, 45, 0)
wtitle$ = "[Status of room" +
STR$(rn%) + "]"
blnk$ = STRING$(LEN(wtitle$), "
")
LOCATE 8, 10: COLOR fc%, bc%:
PRINT blnk$; : LOCATE 8, 10:
PRINT wtitle$; : COLOR fc%, bc%
LOCATE 9, 5:
COLOR bc%, fc%
PRINT USING "Bldg vol #,#### m2
Ci ##,###.# mg/m3"; vot; c0;
COLOR fc%, bc%
LOCATE 10, 6: PRINT USING "vol.
#### m3 Wall ### m2  sink ##.##
"; volume, area, sinks(rn%, 1);
LOCATE 11, 6: PRINT "Sources
selected :";
row% = 12: col% = 5
FOR i% = 1 TO subitems%(3)
 IF row% < 14 THEN
  col% = 6
  r% = row%
  ELSE
   col% = 15
   r% = r% + 1
END IF
  IF  sstrength(rn%,  i%,
pollutant%) * xnsource(rn%, i%,
pollutant%) > 0 THEN
    LOCATE  r%,  col%:  PRINT
sources$(rn%, i%);
    row% = row% + 1
    IF row% = 14 THEN r% = 11
 END IF
NEXT i%
CALL windmake(mon%, fc%, bc%, 9,
43, 16, 78, 0)
COLOR bc%, fc%
LOCATE 8, 50: PRINT "[Air flows
]"; : COLOR fc%, bc%
LOCATE 9, 46: PRINT "Air  flows
 Case 1   Case2 "
LOCATE 10, 45: PRINT USING "Air
from HVAC      ####.#  ####.#";
vin(rn%, 0, 1), vin(rn%, 0, 0);
LOCATE 11, 45: PRINT USING "Air
to HVAC        ####.#  ####.#";
vout(rn%, 0, 1), vout(rn%, 0,
0);
LOCATE 12, 45: PRINT USING "Air
from Outdoor ####.#  ####.#";
ambin(rn%, 1), ambin(rn%, 0);
LOCATE 13, 45: PRINT USING "Air
to outdoors   ####.#  ####.#";
ambout(rn%, 1), ambout(rn%, 0);
row% = 16
col% = 5
tvin(1)  =  vin(rn%,  0,  1)  +
ambin(rn%,  1):  tvout(1)  =
vout(rn%, 0, 1) + ambout(rn%, 1)

tvin(0)  =  vin(rn%,  0,  0)  +
ambin(rn%,  0):  tvout(0)  =
ambout(rn%, 0) + vout(rn%, 0, 0)

CALL  windmake(mon%,  fc%,  bc%,
16, 3, 23, 58, 0)
COLOR bc%, fc%
LOCATE   15,   7:   PRINT
"[Interconnections]";  :  COLOR
fc%, bc%
LOCATE row%, col%: PRINT "Room#
 Air out to    Air in from"
row% = row% + 1
REM for j= 0 to 1
FOR i% = 1 TO subitems%(1)
IF rn% <> i% THEN
 FOR j = 0 TO 1
 tvin(j)  =  tvin(j)  +  vin(rn%,
i%, j): tvout(j) = tvout(j) +
vout(rn%, i%, j)
 NEXT j
 IF vout(rn%, i%, 0) OR vin(rn%,
i%, 0) OR vout(rn%, i%, 1) OR
vin(rn%, i%, 1) > 0 THEN
 LOCATE row%, col%: PRINT i%;
   LOCATE row%, col% + 15: PRINT
USING "###.#"; vout(rn%, i%, 0);

   LOCATE row%, col% + 31: PRINT
USING "###.#"; vin(rn%, i%, 0);

 LOCATE row%, col% + 9
  PRINT USING "###.#"; vout(rn%,
i%, 1);
 LOCATE row%, col% + 25: PRINT
USING "###.#"; vin(rn%, i%, 1);
 row% = row% + 1
END IF
 END IF
NEXT i%
FOR j = 0 TO 1
IF tvin(j) > 0 THEN balance(j) =
tvin(j) - tvout(j)
NEXT j
CALL  windmake(mon%,  fc%,  bc%,
17, 48, 22, 79, 0)
COLOR bc%, fc%
LOCATE  16,  50:  PRINT  "[Air
Balances]"; : COLOR fc%, bc%
LOCATE 17, 51: PRINT "
 Case 1   Case 2";
LOCATE 18, 50: PRINT USING "Air
entering  ####.#      ####.#";
tvin(1), tvin(0);
LOCATE 19, 50: PRINT USING "Air
leaving    ####.#      ####.#";
tvout(1), tvout(0);
LOCATE  20,  50:  PRINT  USING
"Balance        ####.#  ####.#";
balance(1), balance(0);
END SUB

REM******************************
*********************************
***************
SUB default (nrooms%) STATIC
SHARED  conc,  ventotal,  thvac,
ambair,   fracton,   partcont,
orgcont
SHARED sources$(), nsources%(),
sinks(), nsinks%(), sstrength(),
xnsource()
SHARED volume(), c0(), area(),
floor(), vin(), vout(),
vhvacin()
SHARED vhvacout(), vambin(),
vambout()
CALL readdat(nrooms%,
pollutant%, "default.rom")
onecig = 30
END SUB

DEFINT E, R
SUB defpol STATIC
SHARED pollutant$(), pollutant%
CLS
PRINT "                      Select
Pollutant "
PRINT
PRINT "                    Available
pollutants"
FOR j = 1 TO 6: PRINT TAB(10); ,
j, pollutant$(j)
NEXT j
PRINT
PRINT "Press number
corresponding to the pollutant
you wish to use"
pollutant% = 0
WHILE pollutant% = 0
y$ = INPUT$(1)
pollutant% = INSTR("123456", y$)

WEND
CLS
END SUB

SUB displ (time(), tmax%,
concentration(), nrooms%,
volume()) STATIC
SHARED xmassout, xmassemit,
sinkmass, rsinkmass!()
lne% = 0
CLS
CALL massin(concentration(),
nrooms%, volume(), xmass, tmax%)

CALL inout("CON")
CLS
PRINT "Cumulative results "
PRINT USING "Cumulative mass
emitted          #,######.#  mg";
xmassemit
PRINT USING "Cumulative mass to
outdoors    #,######.#    mg";
xmassout
PRINT USING "Mass inside at end
of run   #,######.# mg "; xmass
PRINT USING "Cumulative sink
mass              #,######.# mg ";
sinkmass
IF xmassemit <> 0 THEN
PRINT USING "% unaccounted for
          ##.###% "; (xmassemit -
(xmassout + xmass + sinkmass)) *
100 / xmassemit
END IF
LOCATE 25, 10: PRINT "Press any
key to continue. ESC to exit.";
lne% = 0
CALL getkey(y$, y%)
CLS
PRINT "results of indoor air
calculations"
PRINT "day Time(hrs)
   Room
Concentration"
FOR j = 1 TO tmax%
  hr = time(j) * 2.77778E-04
  dayp% = INT(hr - 24) / 24 + 1
  IF dayp% <= 0 THEN dayp% = 1
PRINT dayp%; "  "; : PRINT USING
"###.#"; time(j) * 2.77778E-04;

FOR room% = 0 TO nrooms%
PRINT TAB(30); room%; TAB(50); :
PRINT USING "##.###";
concentration(1, room%, j)
NEXT room%
lne% = lne% + nrooms%
IF lne% > 20 THEN
 LOCATE 25, 10: PRINT "Press any
key to continue. ESC to exit.";

 lne% = 0
 CALL getkey(y$, y%)
 IF y% = 27 THEN EXIT FOR
 CLS
 LOCATE 25, 10: PRINT
STRING$(50, " ");
LOCATE 1, 1: PRINT "day
Time(hrs)                   Room
          Concentration"
END IF
NEXT j
 IF y% <> 27 THEN
 LOCATE 25, 10: PRINT "Press any
key to continue.";
 CALL getkey(y$, y%)
 LOCATE 25, 10: PRINT
STRING$(50, " ");
 END IF
END SUB

DEFSNG E, R
SUB distrib (nrooms%, vtotal,
vambin(), vambout(), vol())
STATIC
 DEFINT J
  FOR j = 1 TO nrooms%
   vambin(j, 1) = vol(j) *
vtotal
   vambout(j, 1) = vambin(j, 1)
   vambin(j, 0) = vambin(j, 1)
   vambout(j, 0) = vambin(j, 1)
  NEXT j
END SUB

REM $STATIC
DEFINT E, R
SUB dterror (deltat)
CLS :
PRINT "ERROR ERROR"
PRINT "It appears that the time
step you have selected is too
large."
```

```
PRINT "Please select SETUP from
the main menu and enter a new
value"
PRINT "of DELTAT."
PRINT USING "A suggested value
is ###.##, which is 70% of the
current value."; deltat * .7
PRINT "Press any key to return
to main menu."
WHILE INKEY$ = "": WEND
END SUB

REM $DYNAMIC
REM labels
SUB endit (endflag, day%,
maxdays%, second, hour, hrsday,
tmax%, t%, time1) STATIC
  tmax% = t% + 1
  endflag = -1
  day% = maxdays% + 1
  second = 3601
  hour = hrsday + 1
  endflag = -1
  t% = tmax%
END SUB

SUB fileit (time(), tmax%,
concentration(), nrooms%) STATIC

CLS
redo% = -1
WHILE redo% = -1
redo% = 1
LINE INPUT "Enter data file name
"; filen$
IF LEN(filen$) > 6 THEN
  filen$ = LEFT$(filen$, 6)
  CLS
  PRINT "Warning"
  PRINT "The filename was too
long and was shortened to ";
filen$
  ty% = 0
  WHILE ty% = 0
    PRINT
    PRINT "If this is
acceptable, press Y"
    PRINT "If you wish to enter
a new filename press N"
    yy$ = INKEY$
    WHILE yy$ = "": yy$ =
INKEY$: WEND
    ty% = INSTR("YyNn", yy$)
    WEND
    IF ty% > 2 THEN redo% = -1
ELSE redo% = 1
END IF
WEND
FOR room% = 0 TO nrooms%
OPEN "O", 1, filen$ +
MID$(STR$(room%), 2, 2 -
LEN(STR$(room%)) + 1) + ".dat"
PRINT #1, "Data for room ";
STR$(room%)
REM print #1,tmax%
FOR j% = 1 TO tmax%
   PRINT #1, time(j%),
concentration(1, room%, j%)
```

```
  NEXT j%
  CLOSE 1
  NEXT room%
END SUB

SUB formr (title$(), numtitles%,
valx(), rowstart%, rowfinish%,
colstart%, colfinish%,
formtitle$) STATIC
DEFINT J
cur$ = "-" + CHR$(16)
CALL cwind(fc%, bc%, 24, 1, 25,
80)
COLOR fc%, bc%
LOCATE 25, 10: PRINT "Use arrow
keys to move cursor Press ESC to
return.";
LOCATE rowstart%, colstart% + 1:
PRINT namtitle$: LOCATE
rowstart%, colfinish% - 8: PRINT
"Value"
jmin% = rowstart%
dcol% = colfinish% - colstart%
spac% = dcol% / 2 + 5
row% = rowstart%: col% =
colstart%
FOR j = 1 TO numtitles%
  LOCATE row%, col%: PRINT
title$(j);
  LOCATE row%, col% + spac%:
PRINT valx(j)
  row% = row% + 1:
NEXT j
row% = rowstart%: col% =
colstart%
y$ = "1"
WHILE ASC(y$) <> 27
COLOR fc%, bc%
 LOCATE row%, col%: COLOR bc%,
fc%: PRINT STRING$(colfinish% -
colstart% - 2, " ")
 LOCATE row%, col%: COLOR bc%,
fc%: PRINT title$(row% -
rowstart% + 1)
 LOCATE row%, col% + spac%:
PRINT valx(row% - rowstart% + 1)

CALL getmove(-1, y$, jy%, row%,
col% - 5, cur$, "-")
IF ASC(y$) <> 27 THEN
IF LEN(y$) = 2 THEN
 LOCATE row%, col%: COLOR fc%,
bc%: PRINT STRING$(dcol% - 2, "
")
 LOCATE row%, col%: PRINT
title$(row% - rowstart% + 1)
 valx(4) = valx(1) * valx(2) *
valx(3)
 LOCATE row%, col% + spac%:
PRINT valx(row% - rowstart% + 1)

  IF RIGHT$(y$, 1) = "P" THEN
   CALL movecursor(-1, row%, col%
- 5, "D", 1, 1, 0, 0)
   IF row% > rowfinish% THEN row%
= rowstart%
   ELSEIF RIGHT$(y$, 1) = "H"
THEN
```

```
  CALL movecursor(-1, row%, col%
- 5, "U", 1, 1, 0, 0)
IF row% < rowstart% THEN row% =
rowfinish%
  ELSE
   dir$ = ""
 END IF
 ELSE
 LOCATE row%, col% + spac%:
COLOR bc%, fc%: PRINT
STRING$(10, " ");
 COLOR fc%, bc%
 CALL getdata(x$, y$, row%, col%
+ spac% + 1)
 valx(row% - rowstart% + 1) =
VAL(x$)
 COLOR fc%, bc%
 LOCATE row%, col% + spac%:
PRINT STRING$(10, " ");
 LOCATE row%, col% + spac%:
PRINT valx(row% - rowstart% +
1);
 END IF
 END IF
WEND
END SUB

SUB formw (title$(), numtitles%,
valx(), rowstart%, rowfinish%,
colstart%, colfinish%,
formtitle$) STATIC
DEFINT J
cur$ = "-" + CHR$(16)
COLOR fc%, bc%
CALL cwind(fc%, bc%, 24, 1, 25,
80)
LOCATE 25, 10: PRINT "Use arrow
keys to move cursor Press ESC to
return.";
LOCATE rowstart%, colstart% + 1:
PRINT namtitle$: LOCATE
rowstart%, colfinish% - 8: PRINT
"Value"
jmin% = rowstart%
dcol% = colfinish% - colstart%
spac% = dcol% / 2 + 5
row% = rowstart%: col% =
colstart%
FOR j = 1 TO numtitles%
  LOCATE row%, col%: PRINT
title$(j);
  LOCATE row%, col% + spac%:
PRINT valx(j)
  row% = row% + 1:
NEXT j
row% = rowstart%: col% =
colstart%
y$ = "1"
WHILE ASC(y$) <> 27
COLOR fc%, bc%
 LOCATE row%, col%: COLOR bc%,
fc%: PRINT STRING$(colfinish% -
colstart% - 2, " ")
 LOCATE row%, col%: COLOR bc%,
fc%: PRINT title$(row% -
rowstart% + 1)
 LOCATE row%, col% + spac%:
PRINT valx(row% - rowstart% + 1)
```

```
CALL getmove(-1, y$, jy%, row%,
col% - 5, cur$, "- ")
IF ASC(y$) <> 27 THEN
IF LEN(y$) = 2 THEN
 LOCATE row%, col%: COLOR fc%,
bc%: PRINT STRING$(dcol% - 2, "
")
 LOCATE row%, col%: PRINT
title$(row% - rowstart% + 1)
 LOCATE row%, col% + spac%:
PRINT valx(row% - rowstart% + 1)

 IF RIGHT$(y$, 1) = "P" THEN
  CALL movecursor(-1, row%, col%
- 5, "D", 1, 1, 0, 0)
  IF row% > rowfinish% THEN row%
= rowstart%
  ELSEIF RIGHT$(y$, 1) = "H"
THEN
  CALL movecursor(-1, row%, col%
- 5, "U", 1, 1, 0, 0)
IF row% < rowstart% THEN row% =
rowfinish%
  ELSE
   dir$ = ""
 END IF
 ELSE
 LOCATE row%, col% + spac%:
COLOR bc%, fc%: PRINT
STRING$(10, " ");
 COLOR fc%, bc%
 CALL getdata(x$, y$, row%, col%
+ spac% + 1)
 valx(row% - rowstart% + 1) =
VAL(x$)
 COLOR fc%, bc%
 LOCATE row%, col% + spac%:
PRINT STRING$(10, " ");
 LOCATE row%, col% + spac%:
PRINT valx(row% - rowstart% +
1);
 END IF
 END IF
WEND
END SUB

DEFSNG E, R
SUB gasclean (pthvac) STATIC
REDIM x(5), title$(5)
formtitle$ = "Air cleaner"
title$(1) = "Operating
efficiency %"
x(1) = (1 - pthvac) * 100
CALL form(mon%, fc%, bc%,
title$(), "Item", 1, x(), 12,
12, 10, formtitle$)
pthvac = (100 - x(1)) / 100
COLOR fc%, bc%
END SUB

DEFINT E, R
SUB gconfig (mon$, mon%) STATIC
OPEN "I", 1, "CONFIG.IND"
CLOSE 1
OPEN "I", 1, "CONFIG.ind"
INPUT #1, mon$
  INPUT #1, mon%, xaxismin%,
xaxismax%, yaxismin%, yaxismax%,
xstep%, ystep%
  FOR j = 0 TO 10: INPUT #1,
colr%(j): NEXT j
  CLOSE 1
IF mon$ = "MON" THEN
   bc% = 0
   fc% = 15
  ELSE
  bc% = 3
  fc% = 8
END IF
CLOSE
END SUB

DEFSNG E, R
SUB getchr (y$) STATIC
 y$ = INKEY$
 WHILE y$ = ""
  y$ = INKEY$
 WEND
 END SUB

DEFINT E, R
SUB getrooms (nrooms%, jnplot%,
jroom%()) STATIC
DEFINT J
PRINT "Plot a limited number of
rooms "
PRINT
PRINT "Please enter the rooms
you want to plot, enter end when
done";
PRINT
a$ = ""
j = 1
WHILE a$ <> "end"
 errflag% = -1
 WHILE errflag% = -1
  a$ = ""
  LINE INPUT a$
  IF a$ = "END" THEN a$ = "end"
 IF a$ <> "end" THEN
 IF VAL(a$) > nrooms% THEN
    PRINT "ERROR. ERROR"
    PRINT "There are only ";
nrooms%; " rooms allowed"
  ELSE
   errflag% = 0
   IF VAL(a$) >= 0 THEN
   jroom(j) = VAL(a$)
    j = j + 1
    END IF
    IF j > nrooms% + 1 THEN
    j = nrooms% + 1
    a$ = "end"
    END IF
  END IF
  ELSE
   errflag% = 0
   j = j - 1
  END IF
   WEND
WEND
jnplot% = j
END SUB

SUB gfile (filename$) STATIC
LOCATE 12, 12: PRINT "Please
enter file name w/o extension."
LOCATE 13, 12: PRINT "Type DIR
for directory. "
LOCATE 14, 12: PRINT "Enter Q to
return."
LOCATE 15, 12: PRINT STRING$(20,
" ")
LOCATE 15, 12: LINE INPUT
filename$
LOCATE 16, 12
END SUB

DEFSNG E, R
SUB ghvac (new1%, fracton,
thvac, ambair, opcyc, volume)
STATIC
REDIM x(5), title$(5)
new1% = 2
formtitle$ = "HVAC"
title$(1) = "Operating flow air
changes/hr"
title$(2) = "% Makeup air"
title$(3) = "Fraction of time on
(0-1)"
title$(4) = "Volume m3"
x(1) = thvac: x(2) = ambair:
x(3) = fracton: x(4) = volume
CALL form(mon%, fc%, bc%,
title$(), "Item", 4, x(), 12,
15, 10, formtitle$)
thvac = x(1): ambair = x(2):
fracton = x(3): volume = x(4)
COLOR fc%, bc%
END SUB

DEFINT E, R
SUB help STATIC
CLS
COLOR fc%, bc%
CLS
j = 0
OPEN "I", 1, "Help.ind"
IF erflag% = -1 THEN
 erflag% = 0
 ELSE
WHILE NOT EOF(1)
INPUT #1, a$
j = j + 1
PRINT a$
IF j > 20 THEN
LOCATE 25, 2: PRINT "press any
key to continue.";
CALL getkey(y$, y%)
j = 0
CLS
LOCATE 1, 1
END IF
WEND
LOCATE 25, 1: PRINT "Press any
key to return to program";
CALL getkey(y$, y%)
CLS
LOCATE 1, 1
CLOSE
END IF
END SUB
```

```
DEFSNG E, R
SUB hflow (roomnr%, vin, vout,
case$) STATIC
REDIM x(2), title$(2)
CALL windmake(mon%, fc%, bc%,
10, 35, 16, 78, -1)
title$(1) = "Air entering from
HVAC"
title$(2) = "Air leaving to
HVAC"
x(1) = vin
x(2) = vout
ftitle$ = "[Define HVAC Case] "
+ case$
CALL formw(title$(), 2, x(), 10,
11, 41, 75, ftitle$)
vin = x(1): vout = x(2)
CALL cwind(fc%, bc%, 10, 35, 16,
78)
END SUB

SUB highlight (row%, col%,
title$) STATIC
COLOR bc%, fc%
LOCATE row%, col%: PRINT
STRING$(LEN(title$), " ");
LOCATE row%, col%: PRINT title$;

COLOR fc%, bc%
END SUB

REM $STATIC
DEFINT E, R
SUB house STATIC
OPEN "I", 1, "CONFIG.ind"
INPUT #1, mon$
   INPUT #1, mon%, xaxismin%,
xaxismax%, yaxismin%, yaxismax%,
xstep%, ystep%
   FOR j = 0 TO 10: INPUT #1,
colr%(j): NEXT j
   CLOSE 1
IF mon$ = "MONO" THEN
     bc% = 0
     fc% = 15
   ELSE
     bc% = 3
     fc% = 8
END IF
CLOSE
IF mon$ <> "MONO" THEN
REM draw house
 SCREEN 1: WIDTH 40
CLS
LINE (40, 140)-(200, 50), 1, B
LINE (40, 50)-(120, 15), 1
LINE (200, 50)-(120, 15), 1
PAINT (105, 43), 2, 1
LINE (80, 75)-(100, 60), 1, B
PAINT (125, 60), 2, 1
LINE (110, 140)-(130, 100), 1, B

PAINT (124, 60), 2, 1
COLOR 1, 3
LOCATE 11, 7: PRINT " Indoor air
model ";
LOCATE 12, 7: PRINT " V. 1.2
5/2/88 ";
```

```
LOCATE 13, 7: PRINT " By LES
AEERL-RTP ";
LOCATE 10, 28: PRINT "Press
any";
LOCATE 12, 28: PRINT "key to ";
LOCATE 14, 28: PRINT "continue."

WHILE INKEY$ = "": WEND
END IF
CLS
REM screen 0:width 80
REM color fc%,bc%
END SUB

REM $DYNAMIC
DEFSNG E, R
SUB hvac (new1%, fracton, thvac,
ambair, c0, opcyc, pthvac,
volume, nrooms%, vin(), vout())
STATIC
REDIM title$(10), bal(nrooms%)
new1% = 2
startrow% = 9: newrow% = 1:
startcol% = 30: nummtitle% = 5:
title$(1) = "<G>eneral
Description"
title$(2) = "Define <A>ir
Cleaning"
title$(3) = "Define <S>ources"
title$(4) = "Define room
<F>lows"
title$(5) = "<Q>uit"
menutitle$ = "Menu for HVAC"
c0 = 0
choice% = 0
newrow% = 1
WHILE choice% < 5
startrow% = newrow% + 8
IF startrow% > 13 THEN startrow%
= 13
ok$ = "GASFQ"
CALL menu(fc%, bc%, ok$,
title$(), startrow%, newrow%,
startcol%, nummtitle%,
menutitle$, choice%)
newrow% = choice%
SELECT CASE choice%
  CASE 1
     CALL ghvac(n1%, fracton,
thvac, ambair, opcyc, volume)
  CASE 2
   CALL gasclean(pthvac)
  CASE 3
  CALL hvacsourc(ktype%)
  CASE 4
        CALL inter(0, nrooms%,
vin(), vout())
         CALL sbalance(vin(),
bal(), nrooms%)
CASE ELSE
END SELECT
WEND
END SUB

DEFINT E, R
SUB hvac2 (fracton, ncycles%,
jhv, rs%, pthvac, pt) STATIC
IF ncycles% <= 0 THEN
```

```
  hvon%    =    fnhvon(fracton,
ncycles%)
   IF hvon% = 1 THEN
     ncycles% = 15
      jhv = 1
    ELSE
      jhv = 0
      ncycles% = 2
    END IF
  IF jhv = 0 THEN
      rs% = 1
      pt = 1
   ELSE
      rs% = 0
      pt = pthvac
  END IF
  ELSE
   ncycles% = ncycles% - 1
  END IF
IF jhv = 1 THEN rs% = 0 ELSE rs%
= 1
END SUB

DEFSNG E, R
SUB hvacsourc (j%) STATIC
CLS
PRINT "Define source in hvac"
PRINT "Select type of source"
PRINT  "1.  Constant  rate  =
20mg/hr"
PRINT "2. 0 if conc>5 mg/m3 30
if conc<5 mg/m3"
PRINT "3. No source"
PRINT
PRINT "Press key corresponding
to your selection."
y$ = INPUT$(1): j% = VAL(y$)
END SUB

SUB ind87
SHARED  vhvacin(),  vhvacout(),
vambin(), vambout()
SHARED   outmenu$(),   time(),
tmax%,   pconc(),    nrooms%,
plotmenu$()
SHARED nmenu(), conc
newrow% = 1
subitems%(1) = nrooms%
startrow% = 8: startcol% = 30
nummtitle% = nmenu(1)
choice% = 1
newrow% = 1
calcflag% = 0
menutitle$ = "Main control menu"

WHILE choice% <> nmenu(1)
REM goto 999
IF newrow% > 6 THEN newrow% = 6
ok$ = "ECOPSQ"
CALL   menu(fc%,   bc%,   ok$,
mainmen$(), startrow%, newrow%,
startcol%,   nummtitle%,
menutitle$, choice%)
newrow% = choice%
SELECT CASE choice%
    CASE 1
       newrow% = 2
       select1% = 0
```

```
  nrow% = 1
  WHILE select1% <> nmenu(2)
          ok$ = "PBHORSGQ"
          CALL menu(fc%, bc%, ok$,
inmenu$(), 9, nrow%, startcol%,
nmenu(2),   "Data   Input",
select1%)
          SELECT CASE select1%
          CASE 1
  CALL defpol
          nrow% = select1%
          CASE 2
  CALL   building(nrooms%,
ventotal  newrow%)
  subitems%(1) = nrooms%
  nrow% = select1%
  CASE 3
  CALL  hvac(newrow%,  fracton,
thvac,  ambair,  c0(0),  opcyc,
pthvac,  volume(0),  nrooms%,
vin(), vout())
     sum = 0
     FOR j = 1 TO nrooms%: sum =
sum + vin(0, j, 1): NEXT j
     vambin(0, 1) = sum * ambair
/ 100
     vambout(0, 1) = vambin(0, 1)
  nrow% = select1%
  CASE 4
   CALL outside(conc, newrow%)
   nrow% = select1%
  CASE 5
   CALL sroom
   nrow% = select1%
  CASE 6
  nrow% = select1%
  CALL   storedat(nrooms%,
pollutant%)
  nrom% = 6
        CASE 7
  nrow% = select1%
   CALL   readdat(nrooms%,
pollutant%, "")
   subitems%(1) = nrooms%
   nrow% = select1%
        CASE ELSE
        select1% = nmenu(2)
     END SELECT
    WEND
    newrow% = 2
  CASE 2
    newrow% = 3
    hour = 0
    CALL calculate
    newrow% = 3
CASE 3
     select1% = 0
     nrow% = 1
     WHILE select1% <> nmenu(3)
    ok$ = "DWPQ"
    CALL  menu(fc%,  bc%,  ok$,
outmenu$(),  10,  nrow%,
startcol%,  nmenu(3),  "Output
options", select1%)
       SELECT CASE select1%
          CASE 1
          CALL displ(time(), tmax%,
pconc(), nrooms%, volume())
```

```
       nrow% = select1%
      CASE 3
      CALL lprnt(time(), tmax%,
pconc(), nrooms%)
      nrow% = select1%
   CASE 2
     CALL fileit(time(), tmax%,
pconc(), nrooms%)
     nrow% = select1%
    CASE ELSE
    select1% = nmenu(3)
    END SELECT
    WEND
   newrow% = choice%
CASE 4
   IF mon$ = "MONO" OR mon$ =
"mono" THEN
   CLS
   BEEP
   PRINT
   PRINT
   PRINT "Graphics not available
with monochrome"
   PRINT  "Press  any  key  to
return"
   CALL getkey(y$, y%)
  ELSE
  select1% = 0
   nromw% = 1
   WHILE select1% <> nmenu(4)
  ok$ = "PSGQ"
  CALL   menu(fc%,   bc%,   ok$,
plotmenu$(),    10,    nromw%,
startcol%,    nmenu(4),    "Plot
options", select1%)
   nromw% = select1%
 SELECT CASE select1%
   CASE 1
     IF tmax% > maxpoints THEN
tmax% = maxpoints
      CALL     plotem(time(),
pconc(), tmax%, nrooms%)
     SCREEN 0
    WIDTH 80
    COLOR fc%, bc%
   CASE 2
     CLS
      IF tmax% > maxpoints THEN
tmax% = maxpoints
       CALL   plotroom(time(),
pconc(), tmax%, nrooms%)
      SCREEN 0: WIDTH 80
      COLOR fc%, bc%
   CASE 3
      CALL   retriveit(time(),
tmax%, pconc())
   CASE ELSE
   select1% = nmenu(4)
  END SELECT
  WEND
 END IF
  newrow% = choice%
 CASE 5
  CALL setup1(-1)

CASE ELSE
  END SELECT
WEND
```

```
END SUB

DEFINT E, R
SUB init2 STATIC
SHARED  vhvacin(),  vhvacout(),
nmenu(), mainmen$(), maxrooms%
DEFINT J
FOR  j%  =  1  TO  maxrooms%:
vhvacin(j%, 0) = 0: vhvacout(j%,
0) = 0: NEXT j%
calstep% = 10
prntstep% = 30
j = 1
nmenu(1) = 0
WHILE nmenu(1) = 0
READ mainmen$(j)
IF  mainmen$(j)  =  "end"  THEN
nmenu(1) = j - 1
j = j + 1
WEND
END SUB

SUB inout (a$) STATIC
SHARED nrooms%, vin(), vout()
REDIM    t(10)    AS    INTEGER,
fout(nrooms%), fin(nrooms%)
t(1) = 7: FOR j = 2 TO nrooms%:
t(j) = t(j - 1) + 7: NEXT j
a$ = "####"
CLS : SCREEN 0:
COLOR fc%, bc%
PRINT "Input data for run"
PRINT  "Number   of   rooms   ";
nrooms%
FOR jc = 1 TO 2
PRINT "Room flows for case "; jc

PRINT "Room # ";
FOR  j  =  1  TO  nrooms%:  PRINT
TAB(t(j)); j; : NEXT j: PRINT
"Total"
FOR j = 1 TO nrooms%
  PRINT j;
  fin(j) = 0
  fout(j) = 0
  FOR k = 1 TO nrooms%
    IF k <> j THEN
     fin(j) = vin(j, k, jc) +
fin(j)
     fout(j) = vout(j, k, jc) +
fout(j)
     PRINT  TAB(t(k)); : PRINT
USING a$; vin(j, k, jc);
    ELSE
      PRINT TAB(t(k)); "--";
    END IF
    NEXT k
    PRINT USING a$; fin(j)
   NEXT j
       FOR j = 1 TO nrooms%:
   PRINT TAB(t(j)); : PRINT USING
a$; fout(j); :
       NEXT j
     PRINT
     PRINT "Bal ";
      FOR j = 1 TO nrooms%:
  PRINT TAB(t(j)); : PRINT USING
a$; fin(j) - fout(j);
```

```
     NEXT j
   PRINT
   PRINT "Press any key to
continue"
  CALL getkey(y$, y%)
  CLS
 NEXT jc
END SUB

DEFSNG E, R
SUB inter (roomnr%, nrooms%,
vin(), vout()) STATIC
  REDIM r2%(nrooms%)
     IF roomnr% = 0 THEN rowmax%
= nrooms% + 7 ELSE rowmax% =
nrooms% + 6
     CLS
     CALL windmake(mon%, fc%,
bc%, 3, 3, rowmax% + 5, 75, 0)
     LOCATE 4, 5
     PRINT USING " Enter data
for air entering and leaving
room ### m3/hr"; roomnr%;
     PRINT
     LOCATE 25, 1: PRINT
STRING$(80, " ");
     LOCATE 25, 10:
     PRINT "Use arrow keys to
move cursor. Press <ESC> to
return";
     col% = 5: row% = 7
     LOCATE row% - 2, 30:
     PRINT "HVAC on"; TAB(40);
"Hvac off"; TAB(50); "HVAC on";
TAB(60); "Hvacoff"
     LOCATE row% - 1, col%:
     PRINT "Room number";
TAB(30); "Air entering from";
TAB(50); "Air exiting to";
     LOCATE row%, col%: PRINT
TAB(30); "m3/hr "; TAB(50);
"m3/hr";
     row% = 8
     k% = 1
     IF roomnr% = 0 THEN jstart%
= 0 ELSE jstart% = 1
     FOR j% = jstart% TO nrooms%

        IF j% <> roomnr% THEN
       r2%(k%) = j%: k% = k% + 1
       LOCATE row%, col%, 0:
       PRINT j%; TAB(30);
vin(roomnr%, j%, 1); TAB(40);
vin(roomnr%, j%, 0);
       PRINT TAB(50);
vout(roomnr%, j%, 1); TAB(60);
vout(roomnr%, j%, 0)
       row% = row% + 1
        END IF
     NEXT j%
    row% = 8
    COLOR bc%, fc%: LOCATE row%,
col%, 0: PRINT STRING$(65, " ");

    LOCATE row%, 5:
    PRINT r2%(row% - 7);
TAB(30); vin(roomnr%, r2%(row% -
7), 1); TAB(40); vin(roomnr%,
r2%(row% - 7), 0);
    PRINT TAB(50); vout(roomnr%,
r2%(row% - 7), 1); TAB(60);
vout(roomnr%, r2%(row% - 7), 0);

    y% = 0
    col% = 30
    LOCATE row%, col%
    WHILE y% <> 27
      LOCATE row%, col%, 1
      CALL getkey(y$, y%)
      IF y% <> 27 THEN
      IF LEN(y$) = 2 THEN
 y$ = RIGHT$(y$, 1)
 SELECT CASE y$
   CASE "M"
     SELECT CASE col%
      CASE 40
        col% = 50
        LOCATE row%, col%, 1
      CASE 60
        col% = 30
        LOCATE row%, col%, 1
      CASE 50
        col% = 60
        LOCATE row%, col%, 1
      CASE 30
        col% = 40:
        LOCATE row%, col%, 1
      CASE ELSE
   END SELECT
       CASE "K"
  SELECT CASE col%
    CASE 60
     col% = 50
     LOCATE row%, col%, 1
   CASE 50
    col% = 40
    LOCATE row%, col%, 1
   CASE 40
    col% = 30
    LOCATE row%, col%, 1
   CASE 30
    col% = 60
     LOCATE row%, col%, 1
   CASE ELSE
 END SELECT
      CASE "P"
 col% = 30
 COLOR fc%, bc%: LOCATE row%, 5,
0: PRINT STRING$(65, " ");
 LOCATE row%, 5:
 PRINT r2%(row% - 7); TAB(30);
vin(roomnr%, r2%(row% - 7), 1);
TAB(40); vin(roomnr%, r2%(row% -
7), 0);
 PRINT TAB(50); vout(roomnr%,
r2%(row% - 7), 1); TAB(60);
vout(roomnr%, r2%(row% - 7), 0);

 IF row% < rowmax% THEN row% =
row% + 1 ELSE row% = 8
 COLOR bc%, fc%: LOCATE row%, 5,
0: PRINT STRING$(65, " ");
 LOCATE row%, 5:
 PRINT r2%(row% - 7); TAB(30);
vin(roomnr%, r2%(row% - 7), 1);
TAB(40); vin(roomnr%, r2%(row% -
7), 0);
     PRINT TAB(50);
vout(roomnr%, r2%(row% - 7), 1);
TAB(60); vout(roomnr%, r2%(row%
- 7), 0);
      CASE "H"
     col% = 30
     COLOR fc%, bc%: LOCATE
row%, 5, 0: PRINT STRING$(65, "
");
     LOCATE row%, 5:
     PRINT r2%(row% - 7);
TAB(30); vin(roomnr%, r2%(row% -
7), 1); TAB(40);
     PRINT vin(roomnr%, r2%(row%
- 7), 0); TAB(50); vout(roomnr%,
r2%(row% - 7), 1); TAB(60);
     PRINT vout(roomnr%,
r2%(row% - 7), 0);
     IF row% > 8 THEN row% =
row% - 1 ELSE row% = rowmax%
     COLOR bc%, fc%: LOCATE
row%, 5, 0: PRINT STRING$(65, "
");
     LOCATE row%, 5:
     PRINT r2%(row% - 7);
TAB(30); vin(roomnr%, r2%(row% -
7), 1); TAB(40);
     PRINT vin(roomnr%, r2%(row%
- 7), 0); TAB(50); vout(roomnr%,
r2%(row% - 7), 1); TAB(60);
     PRINT vout(roomnr%,
r2%(row% - 7), 0);
     CASE ELSE
     END SELECT
    ELSE
     LOCATE row%, col%, 0: PRINT
"    ";
     CALL getdata(ans$, y$,
row%, col%)
     SELECT CASE col%
       CASE 30
      vin(roomnr%, r2%(row% -
7), 1) = VAL(ans$)
      COLOR bc%, fc%: LOCATE
row%, col%: PRINT STRING$(10, "
");
      LOCATE row%, col%, 0:
PRINT vin(roomnr%, r2%(row% -
7), 1);
      CASE 50
      COLOR bc%, fc%: LOCATE
row%, col%: PRINT STRING$(10, "
");
      vout(roomnr%, r2%(row% -
7), 1) = VAL(ans$)
      LOCATE row%, col%, 0:
PRINT vout(roomnr%, r2%(row% -
7), 1);
      CASE 40
      vin(roomnr%, r2%(row% -
7), 0) = VAL(ans$)
      COLOR bc%, fc%: LOCATE
row%, col%: PRINT STRING$(9, "
");
      LOCATE row%, col%: PRINT
vin(roomnr%, r2%(row% - 7), 0);
       CASE 60
      vout(roomnr%, r2%(row% - 7),
0) = VAL(ans$)
      COLOR bc%, fc%: LOCATE row%,
col%: PRINT STRING$(9, " ");
      LOCATE row%, col%: PRINT
vout(roomnr%, r2%(row% - 7), 0);

       CASE ELSE
     END SELECT
    END IF
   END IF
    COLOR fc%, bc%
 WEND
   CLS
   REM now set vin(i,j)=vout(j,i)
and vout(i,j)=vin(j,i)
   FOR jk% = 0 TO 1
   FOR j% = 1 TO nrooms%
    IF j% <> roomnr% THEN
      vout(j%, roomnr%, jk%) =
vin(roomnr%, j%, jk%)
      vin(j%, roomnr%, jk%) =
vout(roomnr%, j, jk%)
    END IF
 NEXT j%
 NEXT jk%
END SUB

SUB kheatdef (ss, btu, on1,
off1, on2, off2, on3, off3)
STATIC
REDIM x(8), title$(8)
CALL windmake(mon%, fc%, bc%,
10, 39, 19, 79, -1)
LOCATE 9, 41: PRINT "Define
K-heater source strength ";
title$(1) = "mg/KJ"
title$(2) = "Size of heater
KJ/hr"
title$(3) = "Time on 24 hr"
title$(4) = "Time off 24 hr"
title$(5) = "2nd time on"
title$(6) = "2nd time off"
title$(7) = "3rd time on"
title$(8) = "3rd time off"
x(1) = ss
x(2) = btu
x(3) = on1: x(4) = off1: x(5) =
on2: x(6) = off2: x(7) = on3:
x(8) = off3
CALL formw(title$(), 8, x(), 10,
17, 41, 75, "[Define Kheat]")
ss = x(1): btu = x(2)
on1 = x(3): on2 = x(5): on3 =
x(7)
off1 = x(4): off2 = x(6): off3 =
x(8)
CALL cwind(fc%, bc%, 9, 39, 19,
79)
END SUB

DEFINT E, R
SUB lprnt (time(), tmax%,
concentration(), nrooms%) STATIC
SHARED xmassout, xmassemit,
sinkmass, rsinkmass!()
lne% = 0
```

```
CLS
CALL    massin(concentration(),
nrooms%, volume(), xmass, tmax%)

CLS
PRINT  "Hardcopy  routine.   Be
sure printer is ready."
LPRINT "Cumulative results "
LPRINT  USING  "Cumulative  mass
emitted          #,######.#  mg";
xmassemit
LPRINT USING "Cumulative mass to
outdoors    #,######.#    mg";
xmassout
LPRINT USING "Mass inside at end
of run    #,######.# mg "; xmass

LPRINT   USING   "Cumulative  sink
mass             #,######.# mg  ";
sinkmass
LPRINT USING "% accounted for
          ##.###% "; (xmassemit -
(xmassout + xmass + sinkmass)) /
xmassemit * 100
CLS
lne% = 0
LPRINT  "results  of  indoor  air
calculations"
LPRINT "Day    Time(hrs)
     Room
Concentration"
FOR j = 1 TO tmax% - 1
 IF INKEY$ = CHR$(27) THEN EXIT
FOR
 hr = time(j) * 2.77778E-04
 dayp% = INT(hr - 24) / 24 + 1:
IF dayp% <= 0 THEN dayp% = 1
LPRINT  USING  "##        ###.##";
dayp%, time(j) * 2.77778E-04;
FOR room% = 0 TO nrooms%
LPRINT TAB(30); room%; TAB(50);
LPRINT    USING    "###.###";
concentration(1, room%, j)
NEXT room%
lne% = lne% + 3
NEXT j
 END SUB

REM $STATIC
SUB massbal (deltat, second, hr,
rs%,    strength(),    dmass,
concen(),     vambout(),     jhv,
dambout, dsinkmass)
REM subroutine to calculatemass
balances
SHARED nrooms%, rsinkmass!()
SHARED   ssource(),   xnsource(),
pambin()
SHARED sources$(), nsources%(),
sinks(),   nsinks%(),   volume(),
c0()
SHARED   area(),   floor(),   xr(),
xc()
SHARED   pollutant%,    emis2!(),
snk2(), remis2!()
dambout = 0
dmass = 0
dsinkmass = 0
```

```
ddt = deltat * 2.7778E-04
FOR j = rs% TO nrooms%

     dmass = dmass + emis2!(j)
     dambout    =    dambout    +
concen(1, j) * vambout(j, jhv) *
ddt
        rsinkmass!(j)     =
rsinkmass!(j)    +    snk2(j)    -
remis2!(j)
     dsinkmass   =   dsinkmass   +
rsinkmass!(j)

NEXT j
END SUB

REM $DYNAMIC
SUB   massin   (con(),   nrooms%,
volume(), xmass, t%) STATIC
xmass = 0
FOR j = 0 TO nrooms%: xmass =
xmass + volume(j) * con(1, j,
t%): NEXT j
END SUB

SUB menuin (a1$(), n%) STATIC
DEFINT J
j = 1
a$ = ""
WHILE a$ <> "end"
READ a$
 IF a$ <> "end" THEN
 a1$(j) = a$
 j = j + 1
END IF
WEND
n% = j - 1
END SUB

DEFSNG E, R
SUB moth (ss, gms) STATIC
REDIM x(2), title$(2)
CALL  windmake(mon%,  fc%,  bc%,
10, 40, 15, 78, -1)
LOCATE 9, 41: PRINT "Define moth
crystal source strength";
title$(1)    =    "Source    factor
mg/cm2/hr"
x(1) = ss
x(2) = gms
title$(2) = "Area of crystal ";
CALL formw(title$(), 2, x(), 10,
11,    41,     75,     "[Define
mothcrystal")
ss = x(1)
gms = x(2)
CALL cwind(fc%, bc%, 9, 40, 15,
78)
END SUB

SUB other2def (a, B, c, d, ss)
STATIC
REDIM x(5), title$(5)
CALL  windmake(mon%,  fc%,  bc%,
10, 40, 18, 77, -1)
LOCATE     9,     41:       PRINT
"Source=a+b*s+c*exp(d*s)   Enter
a,b,c,d,s";
```

```
x(1) = a: x(2) = B: x(3) = c:
x(4) = d
title$(1) = "a"
title$(2) = "b": title$(3) = "c"

title$(4) = "d"
title$(5) = "s, source strength"

x(5) = ss
CALL formw(title$(), 5, x(), 12,
16, 42, 75, "User source")
a = x(1): B = x(2): c = x(3): d
= x(4): ss = x(5)
CALL cwind(fc%, bc%, 10, 40, 18,
77)
END SUB

SUB otherdef (ss) STATIC
REDIM x(1), title$(1)
CALL windmake(mon%, fc%, bc%,
10, 40, 15, 77, -1)
LOCATE 9, 42: PRINT "[Define
other source]";
title$(1) = "Source strength
mg/hr"
x(1) = ss
CALL formw(title$(), 1, x(), 10,
10, 41, 75, "Define other")
ss = x(1)
CALL cwind(fc%, bc%, 9, 40, 15,
77)
END SUB

SUB outside (concen, new1%)
STATIC
SHARED pollutant$(), pollutant%
REDIM x(1), title$(1)
new1% = 3
CLS
title$(1) =
pollutant$(pollutant%) + "
concentration mg/m3"
x(1) = concen
CALL form(mon%, fc%, bc%,
title$(), "Item", 1, x(), 12,
12, 10, "Outdoor
concentrations")
concen = x(1)
COLOR fc%, bc%
END SUB

DEFINT E, R
SUB plotroom (x(), z(), tmax%,
nrooms%) STATIC
DEFINT J
REDIM jroom(nrooms% + 1)
REDIM y(tmax%)
CALL getrooms(nrooms%, jnplot,
jroom())
errflag% = 0
CLS
PRINT "Setting up plot"
yymin = 1E+29
yymax = -1E+29
xxmax = 1E+29
alog = LOG(10)
FOR jk = 1 TO jnplot
 FOR j = 1 TO tmax%
```

```
   y(j) = LOG(z(1, jroom(jk),
j)) / alog
 NEXT j
 xmax = x(tmax%): xmin = x(1)
IF xmax < xxmax THEN xxmax =
xmax
CALL findmax(y(), ymax, ymin,
tmax%)
IF ymax > yymax THEN yymax =
ymax
IF ymin < yymin THEN yymin =
ymin
IF xmax > xxmax THEN xxmax =
xmax
IF xmin < xxmin THEN xxmin =
xmin
NEXT jk
IF colr%(2) > 1 THEN SCREEN 9
ELSE SCREEN 2
WIDTH 80
ymax = INT(yymax + .999)
ymin = INT(yymin)
xmax = xxmax
xmin = xxmin
FOR j% = 1 TO jnplot
 FOR k = 1 TO tmax%
   y(k) = LOG(z(1, jroom(j), k))
/ alog
 NEXT k
 CALL plot(x(), y(), tmax%,
xmax, xmin, ymax, ymin,
jroom(j))
 LOCATE 25, 10: PRINT "Room ";
jroom(j%); " press any key to
continue";
CALL getkey(y$, y%)
 NEXT j%
SCREEN 0
END SUB

SUB pollution (wax1, wax2, wax3,
wax4, wtime1) STATIC
SHARED sstrength(),
pollutant$(), pstrength()
REDIM wax5(10)
REM pstrength()=default strength
source,pollutant
REM SET UP POLLUTANT SOURCE
STRENGTHS FOR VARIOUS SOURCES
OPEN "I", 1, "Pollutio.dat"
FOR j = 1 TO 6: INPUT #1,
pollutant$(j): NEXT j
FOR j = 1 TO 6: FOR jk = 1 TO 5:
INPUT #1, pstrength(j, jk): NEXT
jk: NEXT j:
FOR j = 1 TO 10: FOR jj = 1 TO
6: FOR jk = 1 TO 5: sstrength(j,
jj, jk) = pstrength(jj, jk)
NEXT jk: NEXT jj: NEXT j
INPUT #1, wax1, wax2, wax3,
wax4, wax5, wtime1
CLOSE
END SUB

DEFSNG E, R
SUB rdef (volume, area, floor)
STATIC
REDIM x(4), title$(4)
```

```
CALL windmake(mon%, fc%, bc%,
10, 45, 17, 78, -1)
LOCATE 9, 46: PRINT "Define room
size ";
title$(1) = "Length m "
title$(2) = "Width  m "
title$(3) = "Height m "
title$(4) = "Volume m3 "
x(4) = volume
x(3) = 2.44
x(1) = SQR(volume / 2.44): x(2)
= x(1)
CALL formr(title$(), 4, x(), 10,
13, 45, 78, "Define Room")
volume = x(4):
 IF ABS(volume - (x(1) * x(2) *
x(3)) / volume) > .001 * volume
THEN
    x(3) = 2.44'assume 8 ft high
room (2.44 meters)
    x(1) = SQR(volume / 2.44):
x(2) = x(1)
END IF
area = x(3) * 2 * (x(1) + x(2))
floor = x(1) * x(2)
CALL cwind(fc%, bc%, 9, 45, 17,
78)
END SUB

SUB readdat (nrooms%,
pollutant%, filename$) STATIC
SHARED conc, sinkst, ventotal,
thvac, ambair, fracton,
partcont, orgcont, sources$()
SHARED nsources%(), sinks(),
nsinks%(), sstrength(),
xnsource(), nsmokers%()
SHARED volume(), c0(), area(),
floor(), vin(), vout()
SHARED vhvacin(), vhvacout(),
vambin(), vambout()
SHARED wax1(), wax2(), wax3(),
wax4(), wax5(), wtime1()
SHARED deltain, prntstep%,
maxdays%, hrsday
SHARED xc(), xr()
CLS
IF filename$ = "" THEN
CALL windmake(mon%, fc%, bc%,
10, 10, 20, 60, 0)
dz = -1
DO
LOCATE 11, 12:
PRINT "Read data from file";
LOCATE 1, 10: PRINT "Available
files ";
FILES "*.rom"
CALL gfile(filename$)
IF filename$ = "q" THEN
filename$ = "Q"
IF filename$ = "Q" THEN EXIT SUB

IF filename$ = "DIR" OR
filename$ = "dir" THEN
 LOCATE 1, 10: PRINT "Available
files ";
 FOR j = 2 TO 9: LOCATE j, 1:
PRINT STRING$(79, " ");
```

```
 NEXT j
 FILES "*.rom"
  ELSE dz = 0
END IF
LOOP UNTIL dz = 0
IF INSTR(filename$, ".") = 0
THEN filename$ = filename$ +
".rom"
END IF
erflag% = -1
WHILE erflag% = -1
  erflag% = 0
OPEN "i", 1, filename$
IF erflag% = -1 THEN
LOCATE 24, 24:  PRINT "ERROR in
opening file.  Reenter file name
";
 DO
   CALL gfile(filename$)
   IF filename$ = "q" THEN
filename$ = "Q"
   IF filename$ = "Q" THEN EXIT
SUB
   IF filename$ = "dir" THEN
filename$ = "DIR"
   IF filename$ = "DIR" THEN
       FILES "*.rom"
   ELSE dz = 0
 END IF
LOOP UNTIL dz = 0
   IF INSTR(filename$, ".") = 0
THEN filename$ = filename$ +
".rom"
END IF
WEND
  INPUT #1, pollutant%, sinkst,
deltain, prntstep%, maxdays%,
hrsday
  INPUT #1, nrooms%
 FOR j = 0 TO nrooms%:
 INPUT #1, cigon(j), cigoff(j)
FOR k = 1 TO 3
  INPUT #1, kheaton(j, k),
kheatoff(j, k)
 INPUT #1, stoveon(j, k),
stoveoff(j, k)
NEXT k
NEXT j
 INPUT #1, conc
 INPUT #1, ventotal
 INPUT #1, thvac
 INPUT #1, ambair
 INPUT #1, fracton
 INPUT #1, partcont
 INPUT #1, orgcont
 INPUT #1, c0(0)
 INPUT #1, volume(0)
REM get source data on file
FOR j = 1 TO nrooms%
   INPUT #1, j, volume(j),
c0(j), area(j), floor(j),
nsources%(j)'volume and sources
  FOR j1 = 1 TO nsources%(j)
    INPUT #1, sources$(j, j1)
  NEXT j1
  FOR j1 = 1 TO nsinks%(j)
    INPUT #1, sinks(j, j1)
     INPUT #1, xr(j), xc(j)
  NEXT j1
 NEXT j
REM now do room ventilation
FOR jhv = 0 TO 1
FOR j = 0 TO nrooms%
   INPUT #1, vambin(j, jhv),
vambout(j, jhv)
 FOR j1 = 0 TO nrooms%
  IF j <> j1 THEN INPUT #1,
vin(j, j1, jhv), vout(j, j1,
jhv)
NEXT j1
NEXT j
NEXT jhv
REM now do sources
FOR room% = 1 TO nrooms%
INPUT #1, nsmokers%(room%)
   FOR s% = 1 TO 5
      FOR p% = 1 TO 6
     INPUT #1, xnsource(room%,
s%, p%), sstrength(room%, s%,
p%)
      NEXT p%
   NEXT s%
NEXT room%
FOR j = 1 TO nrooms%
 INPUT #1, wax1(j), wax2(j),
wax3(j), wax4(j), wax5(j),
wtime1(j)
NEXT j
CLOSE 1
CLS
COLOR fc%, bc%
END SUB

DEFINT E, R
SUB retriveit (time(), tmax%,
concentration()) STATIC
CLS
PRINT "Retrieve data from file
for plotting "
PRINT "Available files are "
FILES "*.dat"
LINE INPUT "Enter data file name
(Q to return to menu) "; filen$

IF filen$ = "q" THEN filen$ =
"Q"
IF filen$ = "Q" THEN
EXIT SUB
ELSE
INPUT "Plot as room number ";
rn%
erflag% = 0
 OPEN "i", 1, filen$ + ".dat"
 IF erflag% = -1 THEN
   PRINT "ERROR. File not found"

   erflag% = 0
   STOP
 ELSE
INPUT #1, room$
j% = 1
WHILE NOT EOF(1)
  INPUT #1, time(j%),
concentration(1, rn%, j%)
  j% = j% + 1
 WEND
```

```
  CLOSE 1
  tmax% = j% - 1
END IF
END IF
END SUB

SUB roomcal (rs%, jhv, second,
hr, concen(), sourcflag%(),
pt(), strength(), xmassout,
xmassemit, sinkmass, dtflag%)
SHARED nrooms%, rsinkmass!(),
emav!, emis1!(), emis2!()
SHARED sinks(), nsinks%(),
volume(), snk1(), snk2(),
remis1!(), remis2!()
REM $DYNAMIC
REDIM c1(maxpollutants, nrooms%)

REDIM ct(maxpollutants,
nrooms%), cout(maxpollutants,
nrooms%)
REDIM ym(10)
nstep = 2
ddt = deltat * 2.77778E-04
h = deltat / nstep
t1 = second: hr1 = hour
sflag% = 0
emav! = 0
REM first call
CALL concroom(rs%, concen(),
c1(), t1, hr1, jhv%, strength(),
pt(), sourcflag%(), sflag%)
sflag% = 1
FOR j = rs% TO nrooms
   ym(j) = concen(1, j)
   ct(1, j) = concen(1, j) + h *
c1(1, j)
   emis2!(j) = emis1!(j) * h
   remis2!(j) = remis1!(j) * h
   snk2(j) = snk1(j) * h
NEXT j
t1 = second + h: hr1 = hour + t1
* 2.77778E-04
CALL concroom(rs%, ct(), cout(),
t1, hr1, jhv%, strength(), pt(),
sourcflag%(), sflag%)
h2 = 2! * h
FOR k = 2 TO nstep
FOR j = rs% TO nrooms%
xswap = ym(j) + h2 * cout(1, j)
ym(j) = ct(1, j)
 ct(1, j) = xswap
 emis2!(j) = emis2!(j) +
emis1!(j) * h2
 remis2!(j) = remis2!(j) +
remis1!(j) * h2
 snk2(j) = snk2(j) + snk1(j) *
h2
 NEXT j
t1 = t1 + h: hr1 = hour + t1 *
2.77778E-04
CALL concroom(rs%, ct(), cout(),
t1, hr1, jhv%, strength(), pt(),
sourcflag%(), sflag%)
NEXT k
 dtflag% = 1
 FOR j = rs% TO nrooms%
    concen(1, j) = .5 * (ym(j) +
ct(1, j) + h * cout(1, j))
    snk2(j) = .5 * (snk2(j) + h
* snk1(j))
    emis2!(j) = (emis2!(j) + h *
emis1!(j)) * 1.388889E-04
    remis2!(j) = (remis2!(j) + h
* remis1!(j)) * 1.388889E-04
    IF ABS(ym(j) + ct(1, j)) >
100000! THEN
       dtflag% = -1
       EXIT FOR
    END IF
 NEXT j
END SUB

SUB sbalance (vin(), bal(),
nrooms%) STATIC
DEFINT J
vtin = 0: vtout = 0
FOR j = 1 TO nrooms%
  FOR jk = 1 TO nrooms%
   IF j <> jk THEN
    vtin = vin(j, jk, 0) + vtin
    vtout = vin(jk, j, 0) +
vtout
   END IF
NEXT jk
 bal(j) = vtin - vtout
 vtin = 0: vtout = 0
NEXT j
END SUB

SUB scale (pollutant%, scale1)
STATIC
SELECT CASE pollutant%
CASE 1
 scale1 = 1.5
CASE 2
 scale1 = 800
CASE 3
 scale1 = 1000
CASE 4
 scale1 = 500
CASE 5
 scale1 = 50
 CASE 6
 scale1 = 10
CASE ELSE
END SELECT
END SUB

DEFSNG E, R
SUB setup (menudat$(),
nchoices%, subitems%()) STATIC
DEFSTR M
DEFINT J
j% = 1
m = ""
DO UNTIL m = "end"
READ m
IF m <> "end" THEN
 menudat(j%, 0) = m
 j% = j% + 1
END IF
LOOP
nchoices% = j% - 1
i = 1:
FOR j% = 1 TO nchoices%
```

```
  m = ""
  i = 1
  DO UNTIL m = "end"
  READ m
  IF m <> "end" THEN
   menudat(j%, i) = m
   i = i + 1
  ELSE
  subitems%(j%) = i - 1
 END IF
LOOP
NEXT j%
END SUB

DEFINT E, R
SUB setup1 (cflag%) STATIC
SHARED deltain, prntstep%,
maxrooms%, maxsources%
SHARED maxtimes%, maxdays%,
hrsday, sinkst
REDIM title$(9), x(9)
IF cflag% = -99 THEN
maxrooms% = 10
maxsources% = 5
maxtimes% = 740
maxdays% = 1
hrsday = 24
deltain = 25
prntstep% = 10
ELSE
title$(1) = "Deltat"
title$(2) = "Print step"
title$(3) = "Max rooms"
title$(4) = "Maxsources"
title$(5) = "Maxtimes "
title$(6) = "Max days"
IF maxdays% > 1 THEN title$(7) =
"Hours per day" ELSE title$(7) =
"Maxhours"
x(1) = deltain: x(2) =
CSNG(prntstep%)
x(3) = CSNG(maxrooms%): x(4) =
CSNG(maxsources%): x(5) =
CSNG(maxtimes%)
x(6) = CSNG(maxdays%): x(7) =
hrsday:
CALL form(mon%, fc%, bc%,
title$(), "Item", 7, x(), 10,
16, 10, "Set up defaults")
deltain = x(1):
maxrooms% = INT(x(3)):
maxsources% = INT(x(4)):
maxtimes% = INT(x(5))
maxdays% = INT(x(6)): hrsday =
x(7):
prntstep% = INT(x(2)):
IF hrsday > 24 THEN
hrsday = 24:
END IF
IF maxdays% > 1 THEN
 hrsday = 24
 title$(7) = "Hours per day"
END IF
IF maxtimes% > 750 THEN
maxtimes% = 750
END IF
CLS
COLOR fc%, bc%
```

```
END SUB

REM $STATIC
DEFSNG E
SUB sink1 (conc, area, sinkst, xr, xc, sink!, sinkmass!, emiss!)
REM reemitting sink term implemented
emiss! = 0
xsink = conc * area * sinkst!
IF sinkmass! > 2.1 THEN
  IF conc < xc THEN emiss! = xr * (xc - conc) * sinkmass ELSE emiss! = 0
  ctest = emiss! * 2.7778E-04 * deltat
  WHILE ctest > .9 * sinkmass!
    emiss! = .8 * emiss!
    ctest = emiss! * 2.77778E-04 * deltat
  WEND
  END IF
  sink = xsink
END SUB

REM $DYNAMIC
DEFSNG R
SUB sinkdef (sinkrate, remit!, reconc!)
REDIM x(3), title$(3)
CALL windmake(mon%, fc%, bc%, 10, 40, 17, 75, -1)
LOCATE 9, 41: PRINT "[Define Sink term] ";
title$(1) = "Rate to sink "
title$(2) = "Reemission factor "

title$(3) = "Reemission conc"
x(1) = sinkrate
x(2) = remit!
x(3) = reconc!
CALL formw(title$(), 3, x(), 10, 12, 41, 75, "[Define sink]")
CALL cwind(fc%, bc%, 9, 40, 16, 75)
sinkrate = x(1): remit! = x(2): reconc! = x(3)
CALL cwind(fc%, bc%, 10, 40, 17, 78)
END SUB

DEFINT E, R
SUB source (room%, sourc, second, hr, sflag%) STATIC
SHARED sstrength(), xnsource(), pollutant%
SHARED w1, w2, w3, w4, w5, wt
SHARED wax1(), wax2(), wax3(), wax4(), wax5(), wtime1()
SHARED time(), nlit%(), lit%()
SHARED ncig%(), stobtu(), kheatbtu(), gmoth()
cig = 0: xmoth = 0: kheat = 0: stove = 0: cook = 0: sourc = 0
 IF sstrength(room%, 1, pollutant%) * xnsource(room%, 1, pollutant%) > 0 THEN
   IF sflag% = 0 THEN
   CALL cigsourc(deltat, room%, hr, ciga)
   cigt = ciga
   ELSE ciga = cigt
   END IF
   cig = ciga * 3600
 END IF
  IF sstrength(room%, 2, pollutant%) * xnsource(room%, 2, pollutant%) > 0 THEN
   jkh = 1
   kheat = -1
   WHILE kheat = -1
     IF hr >= kheaton(room%, jkh) AND hr <= kheatoff(room%, jkh) THEN
       kheat = fnkero(kheaton(room%, jkh), kheatoff(room%, jkh), sstrength(room%, 2, pollutant%) * xnsource(room%, 2, pollutant%), second)
     END IF
    jkh = jkh + 1
     IF jkh > 3 AND kheat = -1 THEN kheat = 0
   WEND
   END IF
   IF sstrength(room%, 3, pollutant%) * xnsource(room%, 3, pollutant%) > 0 THEN
    jkh = 1
    stove = -1
    WHILE stove = -1
     IF hr >= stoveon(room%, jkh) AND hr <= stoveoff(room%, jkh) THEN
       stove = fnstove(stoveon(room%, jkh), stoveoff(room%, jkh), sstrength(room%, 3, pollutant%) * xnsource(room%, 3, pollutant%), second)
     END IF
     jkh = jkh + 1
     IF jkh > 3 AND stove = -1 THEN stove = 0
   WEND
    END IF
    IF sstrength(room%, 4, pollutant%) * xnsource(room%, 4, pollutant%) > 0 THEN
     xmoth = sstrength(room%, 4, pollutant%) * xnsource(room%, 4, pollutant%)
    END IF
    sourc = kheat + stove + xmoth + cig
    IF sstrength(room%, 6, pollutant%) * xnsource(room%, 6, pollutant%) > 0 THEN
     sourc = sourc + fnoth(hr, sstrength(room%, 6, pollutant%) * xnsource(room%, 6, pollutant%))
    END IF
    IF sstrength(room%, 5,
pollutant%) * xnsource(room%, 5,
pollutant%) > 0 THEN
     w1 = wax1(room%): w2 =
wax2(room%): w3 = wax3(room%):
w4 = wax4(room%): w5 =
wax5(room%): wt = wtime1(room%)
     sourc = sourc + fnwax(hr +
24 * (day% - 1),
sstrength(room%, 5, pollutant%)
* xnsource(room%, 5,
pollutant%))
     END IF
REM
sourc=sourc+fnsource2(a(room%),
b(room%),c(room%),d(room%),stre
ngth(room%,6))
END SUB

DEFSNG E, R
SUB sourcedef (so$, ss,
xnsource, room%, a, B, c, d,
floor) STATIC
SHARED wax1(), wax2(), wax3(),
wax4(), wax5(), wtime1()
SHARED nsmokers%()
SELECT CASE so$
   CASE "Cigs"
      CALL cigdef(ss, xnsource,
nsmokers%(room%), cigon(room%),
cigoff(room%))
 CASE "K-heater"
     CALL kheatdef(ss, xnsource,
kheaton(room%, 1),
kheatoff(room%, 1),
kheaton(room%, 2),
kheatoff(room%, 2),
kheaton(room%, 3),
kheatoff(room%, 3))
 CASE "Unvented-stove"
     CALL stovedef(ss, xnsource,
stoveon(room%, 1),
stoveoff(room%, 1),
stoveon(room%, 2),
stoveoff(room%, 2),
stoveon(room%, 3),
stoveoff(room%, 3))
 CASE "Moth crystals"
    CALL moth(ss, xnsource)
   CASE "other2"
   CALL other2def(a, B, c, d,
ss)
    xnsource = 1
  CASE "Wax"
    CALL waxdef(ss, floor,
wtime1(room%), wax1(room%),
wax2(room%), wax3(room%),
wax4(room%), wax5(room%))
    xnsource = floor:
    CASE ELSE
    CALL otherdef(ss)
    xnsource = 1
END SELECT
END SUB

SUB sroom STATIC
SHARED newrow%, nrooms%,
menudat$(), sources$(),
nsources%(), sinks(), nsinks%(),
nchoices%, subitems%(),
volume(), c0(), area(), floor(),
vin(), vout(), vhvacin(),
vhvacout(), vambin(), vambout()

SHARED wax1(), wax2(), wax3(),
wax4(), wtime1()
SHARED xnsource(), sstrength(),
pollutant%, xr(), xc()
REDIM bal(nrooms%)
 IF pollutant% > 6 THEN
pollutant% = 1
 roomnr% = 1: oldj% = 1: oldcol%
= 1
 newrow% = 4
 CLS
 d$ = ""
 WHILE d$ <> "done"
  vot = 0
  FOR jz = 1 TO nrooms%: vot =
volume(jz%) + vot: NEXT jz
  CALL curstatus(roomnr%, vot,
volume(roomnr%), c0(roomnr%),
area(roomnr%),
nsources%(roomnr%), sinks(),
nsinks%(roomnr%), subitems%(),
sources$(), vin(), vout(),
vhvacin(), vhvacout(), vambin(),
vambout())
  CALL barmenu(oldcol%, oldj%,
menudat(), nchoices%,
subitems%(), choice1%, choice2%)

  IF choice1% = nchoices% THEN
d$ = "done"
  LOCATE 24, 10: PRINT "
                     "; : LOCATE
24, 10
  IF choice2% > 1 THEN
    IF choice1% < nchoices% THEN

      SELECT CASE choice1%
        CASE 1
 roomnr% = choice2% - 1
        CASE 2 'get volume
 SELECT CASE choice2%
  CASE 2
   CALL rdef(volume(roomnr%),
area(roomnr%), floor(roomnr%))
  CASE 3
    CALL c0def(c0(roomnr%))
  CASE ELSE
      END SELECT
     CASE 3
      so$ = menudat(choice1%,
choice2% - 1)
      sources$(roomnr%, choice2%
- 1) = so$
      IF pollutant% > 6 THEN
pollutant% = 1
       CALL sourcedef(so$,
sstrength(roomnr%, choice2% - 1,
pollutant%), xnsource(roomnr%,
choice2% - 1, pollutant%),
roomnr%, a(roomnr%), B(roomnr%),
c(roomnr%), d(roomnr%),
floor(roomnr%))
     CASE 4
```

```
                 CALL
sinkdef(sinks(roomnr%, 1),
xr(roomnr%), xc(roomnr%))
    CASE 5
      cc% = choice2% - 1
      SELECT CASE cc%
        CASE 5
         CALL inter(roomnr%,
nrooms%, vin(), vout())
         CALL sbalance(vin(),
bal(), nrooms%)
       CASE 1
         CALL hflow(roomnr%,
vout(0, roomnr%, 1), vin(0,
roomnr%, 1), "1")
        vin(roomnr%, 0, 1) =
vout(0, roomnr%, 1)
        vout(roomnr%, 0, 1) =
vin(0, roomnr%, 1)
       CASE 2
          CALL hflow(roomnr%,
vout(0, roomnr%, 0), vin(0,
roomnr%, 0), "2")
          vin(roomnr%, 0, 0) =
vout(0, roomnr%, 0):
vout(roomnr%, 0, 0) = vin(0,
roomnr%, 0)
       CASE 3
         CALL ambflow(roomnr%,
vambin(roomnr%, 1),
vambout(roomnr%, 1), "1")
       CASE 4
         CALL ambflow(roomnr%,
vambin(roomnr%, 0),
vambout(roomnr%, 0), "2")
       CASE ELSE
        PRINT "error"
        END SELECT
    CASE ELSE
     d$ = "done"
   END SELECT
  ELSE d$ = "done"
END IF
END IF
WEND
END SUB

SUB storedat (nrooms%,
pollutant%) STATIC
SHARED wax1(), wax2(), wax3(),
wax4(), wax5(), wtime1()
SHARED conc, ventotal, thvac,
ambair, fracton, partcont,
orgcont, sinkst
SHARED sources$(), nsources%(),
sinks(), nsinks%(), sstrength(),
xnsource()
SHARED volume(), c0(), area(),
floor(), vin(), vout(),
vhvacin()
SHARED vhvacout(), vambin(),
vambout(), nsmokers%()
SHARED deltain, prntstep%,
maxdays%, hrsday
SHARED xc(), xr()
DEFINT J
CLS
FILES "*.rom"
```

```
CALL windmake(mon%, fc%, bc%,
10, 10, 20, 50, 0)
LOCATE 11, 12: PRINT "Store data
on file";
LOCATE 12, 12: PRINT "Files
alread written ";
LOCATE 1, 1: FILES "*.rom"
LOCATE 13, 12: PRINT "Please
enter file name";
LOCATE 14, 12: PRINT "with out
extension."
LOCATE 15, 12: PRINT "Enter Q to
return to menu.";
LOCATE 16, 12: LINE INPUT filen$

IF filen$ = "q" THEN filen$ =
"Q"
IF filen$ = "Q" THEN
EXIT SUB
ELSE
IF INSTR(filen$, ".") = 0 THEN
filen$ = filen$ + ".rom"
erflag% = -1
WHILE erflag% = -1
erflag% = 0
OPEN "o", 1, filen$
IF erflag% = -1 THEN
  PRINT "Error in opening file.
Try again"
  INPUT "Enter file name ";
filen$
END IF
WEND
PRINT #1, pollutant%, sinkst,
deltain, prntstep%, maxdays%,
hrsday
PRINT #1, nrooms%
FOR j = 0 TO nrooms%: PRINT #1,
cigon(j), cigoff(j)
 FOR k = 1 TO 3
  PRINT #1, kheaton(j, k),
kheatoff(j, k), stoveon(j, k),
stoveoff(j, k)
 NEXT k
 NEXT j
PRINT #1, conc
PRINT #1, ventotal
PRINT #1, thvac
PRINT #1, ambair
PRINT #1, fracton
PRINT #1, partcont
PRINT #1, orgcont
PRINT #1, c0(0)
PRINT #1, volume(0)
REM get source data on file
FOR j = 1 TO nrooms%
  PRINT #1, j, volume(j), c0(j),
area(j), floor(j),
maxsources%'volume and sources
  FOR j1 = 1 TO maxsources%
    PRINT #1, sources$(j, j1)
  NEXT j1
  FOR j1 = 1 TO nsinks%(j)
    PRINT #1, sinks(j, j1)
    PRINT #1, xr(j), xc(j)
    NEXT j1
  NEXT j
REM now do room ventilation
```

```
FOR jhv = 0 TO 1
FOR j = 0 TO nrooms%
  PRINT #1, vambin(j, jhv),
vambout(j, jhv)
 FOR j1 = 0 TO nrooms%
  IF j <> j1 THEN PRINT #1,
vin(j, j1, jhv), vout(j, j1,
jhv)
NEXT j1
NEXT j
NEXT jhv
REM now do sources
FOR room% = 1 TO nrooms%
PRINT #1, nsmokers%(room%)
   FOR s% = 1 TO 5
      FOR p% = 1 TO 6
     PRINT #1, xnsource(room%,
s%, p%), sstrength(room%, s%,
p%)
      NEXT p%
   NEXT s%
NEXT room%
FOR j% = 1 TO nrooms%
    PRINT #1, wax1(j), wax2(j),
wax3(j), wax4(j), wax5(j),
wtime1(j)
NEXT j

CLOSE 1
END IF
CLS
END SUB

SUB stovedef (ss, btu, on1,
off1, on2, off2, on3, off3)
STATIC
REDIM x(8), title$(8)
CALL windmake(mon%, fc%, bc%,
10, 39, 19, 76, -1)
LOCATE 9, 41: PRINT "Define
stove source strength ";
x(2) = btu
x(1) = ss
x(3) = stoveon: x(4) = stoveoff
title$(1) = "mg/KJ": title$(2) =
"Size heater KJ/hr"
title$(3) = "Time on 24 hr"
title$(4) = "Time off 24 hr"
title$(5) = "2nd time on"
title$(6) = "2nd time off"
title$(7) = "3rd time on"
title$(8) = "3rd time off"
x(3) = on1: x(4) = off1: x(5) =
on2: x(6) = off2: x(7) = on3:
x(8) = off3
CALL formw(title$(), 8, x(), 10,
17, 41, 75, "[Define stove]")
ss = x(1): btu = x(2):
on1 = x(3): on2 = x(5): on3 =
x(7)
off1 = x(4): off2 = x(6): off3 =
x(8)
CALL cwind(fc%, bc%, 9, 39, 19,
76)
END SUB

SUB subtitles (title$(), n%(),
j%, row%, col%) STATIC
```

```
FOR srow% = row% + 1 TO n%(j%) +
1
   LOCATE srow%, col%: PRINT
title$(j%, srow% - 1);
NEXT srow%
END SUB

SUB udim (row%, col%, title$)
STATIC
COLOR fc%, bc%:
LOCATE row%, col%: PRINT
STRING$(LEN(title$), " ");
LOCATE row%, col%: PRINT title$;

END SUB

DEFINT E, R
SUB update (t%, jhv) STATIC
SHARED nrooms%, deltatflag%,
concen(), pconc(), scale1, hour,
nlit%()
SHARED sourcflag%(), volume()
SHARED xmassout, xmassemit,
sinkmass
az$ = STRING$(76, " ")
lenaz% = 76
deltatflag% = 0
xmass = 0
FOR room% = 0 TO nrooms%
  pconc(1, room%, t%) =
concen(1, room%):
  xmass = concen(1, room%) *
volume(room%) + xmass
  cz = concen(1, room%):
  cz = cz * 74 / scale1
 IF cz > 1000000! THEN cz =
1000000!
 IF cz < 0 THEN cz = 0
  IF cz > 74 THEN c% = 74 ELSE
c% = INT(cz)
  bz$ = az$
  IF room% = 0 THEN
   IF jhv = 0 THEN h$ = "O" ELSE
h$ = "H"
   MID$(bz$, 1, 1) = h$
  ELSE
   MID$(bz$, 1, 1) =
RIGHT$(STR$(nlit%(room%,hour)),
1)
 END IF
 IF sourcflag%(room%) = 1 THEN
   MID$(bz$, 2, c%) =
STRING$(c%, "+")
  ELSE
   MID$(bz$, 2, c%) =
STRING$(c%, "-")
 END IF
  LOCATE room% + 2, 4: PRINT
bz$;
NEXT room%
  LOCATE 19, 2: PRINT USING "Cum
mass emitted #####,###.#, mass
out #####,###.#, in bldg mass
#,#####.#  "; xmassemit,
xmassout, xmass;
  IF xmassemit = 0 THEN
xmassemit = -1
  LOCATE 20, 2: PRINT USING
```

```
"Sink mass ####,###.#";
sinkmass;
END SUB

DEFSNG E, R
SUB waxdef (ss, floor, wtime,
wax1, wax2, wax3, wax4, wax5)
STATIC
SHARED w1, w2, w3, w4, w5, wt
REDIM x(8), title$(8)
CALL windmake(mon%, fc%, bc%,
10, 40, 17, 78, -1)
LOCATE 9, 41: PRINT "Define
floor wax source strength";
title$(2) = "1st constant"
x(2) = wax1
title$(1) = "m2 of area ":
x(1) = floor
IF wtime = 0 THEN wtime = wt
IF wax1 = 0 THEN wax1 = w1
IF wax2 = 0 THEN wax2 = w2
IF wax3 = 0 THEN wax3 = w3
x(2) = wax1
title$(3) = "Second constant"
x(3) = wax2: title$(4) = "3rd
constant": x(4) = wax3
title$(5) = "4th constant": x(5)
= wax4
CALL formw(title$(), 5, x(), 10,
14, 41, 75, "[Define floor wax")

IF x(1) * x(2) > 0 THEN ss = 1
ELSE ss = 0
wax1 = x(2)
floor = x(1)
wax2 = x(3): wax3 = x(4): wax4 =
x(5)
CALL cwind(fc%, bc%, 9, 40, 16,
78)
END SUB

SUB wipesub (n%, col%) STATIC
COLOR fc%, bc%
row% = 2
IF col% = 1 THEN
 FOR j% = 1 TO n%
   LOCATE row%, col%: PRINT
STRING$(3, " ");
   row% = row% + 1
  NEXT j%
 ELSE
FOR j% = 1 TO n%
  LOCATE row%, col%: PRINT
STRING$(15, " ");
  row% = row% + 1
NEXT j%
END IF
END SUB

DEFINT E, R
SUB zero (pthvac, pt(),
xmassout, xmassemit, sinkmass)
STATIC
SHARED tmax%, nrooms%, pconc(),
concen(), time(), pambin(),
vambin(), conc, c0()
SHARED t1%, hour, prntcount%,
prntstep%, rsinkmass!()
```

```
REDIM pconc(maxpollutants,
maxrooms%, maxtimes%)
CLS
xmassout = 0: xmassemit = 0:
sinkmass = 0
PRINT
PRINT TAB(20); "Initializing
everything"
ERASE time
 time(t%) = 0
pt(0) = pthvac
FOR j = 1 TO nrooms%: pt(j) = 1:
rsinkmass!(j) = 0: NEXT j
FOR np% = 0 TO maxpollutants:
FOR room% = 0 TO nrooms%:
concen(np%, room%) = 0: NEXT
room%: NEXT np%
REM key (3) off
tmax% = 0
FOR j% = 0 TO nrooms%:
pambin(j%) = vambin(j%, 1) *
conc * 2.77778E-04:
concen(1, j%) = c0(j): pconc(1,
1, 0) = c0(j): NEXT j%
t% = 1: hour = 0: prntcount% =
prntstep%
END SUB
DECLARE SUB ind87 ()
DECLARE SUB help ()
DECLARE SUB main ()
DECLARE SUB menu (fc%, bc%, ok$,
title$(), rows%, newrow%, cols%,
nrows%, menutitle$, choice%)
DECLARE SUB getkey (y$, y%)
DECLARE SUB form (mon%, fc%,
bc%, title$(), namtitle$,
numtitles%, valx!(), rowstart%,
rowfinish%, colstart%,
formtitle$)
DECLARE SUB storepdat
(pollutant$(), pstrength!(),
wax1!, wax2!, wax3!, wax4!,
wtimei!)
DECLARE SUB pollutio ()
DECLARE SUB help1 ()
DECLARE SUB holdit (y$)
DECLARE SUB datsub
(pollutant$(), pstrength!())
REM DECLARE SUB storedat
(pollutant$(), pstrength!(),
wax1!, wax2!, wax3!, wax4!,
wtimei!)
DECLARE SUB indoor ()
COMMON SHARED /c0/ erflag%
COMMON SHARED /c1/ pollutant$(),
pollutant%, pstrength()
COMMON SHARED /c2/ a(), b(),
c(), d(), calflag%, colr%()
COMMON SHARED /c3/ cigon(),
cigoff(), stoveon(), stoveoff(),
kheaton(), kheatoff(), cookon(),
cookoff(), hour, calstep%,
prntstep%
COMMON SHARED /c4/ maxrooms%,
MAXSOURCES%, maxtimes%,
maxdays%, hrsday, mon%, mon$,
sinkst, deltat
COMMON SHARED /c5/ fc%, bc%,
fracton, endflag, day%, second,
deltain, onecig, xaxismin%
COMMON SHARED /c6/ yaxismin%,
yaxismax%, xaxismax%, xstep%,
ystep%, pthvac
COMMON SHARED /c7/ mainmen$(),
inmenu$(), nmenu$(), vin(),
vout(), menudat()
COMMON SHARED /c9/ sources$(),
nsources%(), sinks(), nsinks%(),
nchoices%
COMMON SHARED /c8/ subitems%(),
volume(), c0(), area(), floor()
COMMON SHARED /c10/ vhvacin(),
vhvacout(), vambin(), vambout()

REM main program
REM 3 Dec 1987
DEFSTR T
DEFINT C, J
DATA <R>un indoor air
model,<D>efine source
strengths,<C>onfigure
system,<H>elp,<Q>uit

SUB datsub (pollutant$(),
pstrength()) STATIC
SHARED wax1, wax2, wax3, wax4,
wax5, wtime1
REM SET UP POLLUTANT SOURCE
STRENGTHS FOR VARIOUS SOURCES
OPEN "I", 1, "Pollutio.dat"
FOR j = 1 TO 6: INPUT #1,
pollutant$(j): NEXT j
FOR j = 1 TO 6: FOR jk = 1 TO 5:
INPUT #1, pstrength(j, jk): NEXT
jk: NEXT j
INPUT #1, wax1, wax2, wax3,
wax4, wax5, wtime1
CLOSE
END SUB

SUB help1 STATIC
SHARED fc%, bc%
SCREEN 0, 0, 0: WIDTH 80
 COLOR fc%, bc%: CLS
CLS
PRINT "Help file for indoor air
model"
OPEN "i", 1, "help.ind"
j = 1
a$ = " "
WHILE a$ <> "end"
y$ = " "
LINE INPUT #1, a$
 IF a$ <> "page" THEN
 PRINT a$
 ELSE
 LOCATE 25, 10: PRINT "Press any
key to continue ESC to quit.";
   CALL holdit(y$)
 IF ASC(y$) = (27) THEN a$ =
"end"
 CLS
 END IF
WEND
 IF ASC(y$) <> 27 THEN
 LOCATE 25, 1: PRINT "End of
help. Press any key to
continue.";
CALL holdit(y$)
END IF
13 CLOSE
 COLOR fc%, bc%: CLS
END SUB

SUB holdit (y$) STATIC
100 y$ = INKEY$: IF y$ = "" THEN
100
END SUB

SUB main
DIM t(20)
1 CLS
OPEN "I", 1, "CONFIG.IND"
CLOSE 1
OPEN "I", 1, "CONFIG.ind"
INPUT #1, mon$
  INPUT #1, mon%, xaxismin%,
xaxismax%, yaxismin%, yaxismax%,
xstep%, ystep%
   FOR j = 0 TO 10: INPUT #1,
colr%(j): NEXT j
  CLOSE 1
IF mon$ = "MON" THEN
   bc% = 0
   fc% = 15
  ELSE
  bc% = 3
  fc% = 8
END IF
CLOSE
 COLOR fc%, bc%: CLS

FOR j = 1 TO 5: READ t(j): NEXT
j
done = 0
newrow% = 1
ok$ = "RDCHQ"
WHILE done = 0
CALL menu(fc%, bc%, ok$, t(),
10, newrow%, 30, 5, "Indoor Air
Model Control Menu", choice%)
IF choice% > 0 THEN newrow% =
choice%
IF choice% > 5 THEN newrow% = 1
SELECT CASE choice%
 CASE 1
  CALL ind87
 CASE 2
   CALL pollutio
 CASE 3
   CLS
   PRINT "Configure system"
   PRINT "Current monitor is ";
mon$
    PRINT "Is this correct y or
n";
   y$ = " "
   WHILE INSTR("YynN", y$) = 0
   CALL getkey(y$, y%)
   WEND
IF INSTR("YyNn", y$) > 2 THEN
  CLS
  PRINT "Monitor choices are "
  PRINT "<M>onochrome"
```

```
   PRINT "<C>olor"
   PRINT "<E>GA with color"
   PRINT    "Press    the    key
corresponding to your choice"
  y$ = " "
  WHILE INSTR("MmCcEe", y$) = 0
  y$ = INPUT$(1)
  WEND
y% = INSTR("MmCcEe", y$)
   IF y% > 4 THEN
     mon$ = "EGA"
     mon% = &HB800
     xaxismin% = 101
     yaxismin% = 18
     yaxismax% = 300
     xaxismax% = 700
     ystep% = 14: xstep% = 9:
     FOR j = 0 TO 10: colr%(j) = j
+ 1: NEXT j
  ELSEIF y% > 2 THEN
   mon$ = "COLOR"
   mon% = &HB800
     xaxismin% = 92
     yaxismin% = 8
     yaxismax% = 160
     xaxismax% = 504
     ystep% = 8: xstep% = 8:
     FOR j = 0 TO 10: colr%(j) =
1: NEXT j
   ELSE
   mon$ = "MONO"
   mon% = &HB000
     xaxismin% = 92
     yaxismin% = 8
     yaxismax% = 160
     xaxismax% = 504
     ystep% = 8: xstep% = 8:
     FOR j = 0 TO 10: colr%(j) =
1: NEXT j
   END IF
PRINT "Do you want to save new
configuration y or n?"
  y$ = " "
  WHILE INSTR("YyNn", y$) = 0
  CALL getkey(y$, y%)
  WEND
  IF INSTR("YyNn", y$) < 3 THEN
   OPEN "O", 1, "config.ind"
   PRINT #1, mon$
   PRINT  #1,  mon%,  xaxismin%,
xaxismax%, yaxismin%, yaxismax%,
xstep%, ystep%
   FOR j = 0 TO 10: PRINT #1,
colr%(j): NEXT j
   CLOSE 1
   END IF
END IF
CASE 4
  CALL help
  CASE 5
   done = -1
CASE ELSE
  END SELECT
  WEND
SCREEN 0, 0, 0
CLS
Quit:
END SUB
```

```
SUB pollutio STATIC
SHARED wax1, wax2, wax3, wax4,
wax5, wtime1
REDIM    t$(10),    title$(10),
emfact(10, 10), wtitle$(10)
REDIM x(10)
namtitle$ = "Pollutant"
CALL datsub(title$(), emfact())
done = 0
rowstart% = 10: rowfinish% = 15:
colstart = 15
newrow% = 1
ok$ = "CKUMWOQ"
t$(1)  =  "<C>igarete":  t$(2)  =
"<K>erosene  heater":  t$(3)  =
"<U>nvented stove"
t$(4) = "<M>oth crystals": t$(5)
=  "<W>ax":  t$(6)  =  "<O>ther":
t$(7) = "<Q>uit"
WHILE done = 0
CLS : COLOR fc%, bc%
CALL menu(fc%, bc%, ok$, t$(),
10,  newrow%,  30,  7,  "Select
Source Menu", choice%)
IF choice% > 0 THEN newrow% =
choice%
namtitle$ = "Pollutant"
SELECT CASE choice
 CASE 1
 FOR  j  =  1  TO  6:  x(j)  =
emfact(1, j): NEXT j
   formtitle$ = "Cigerate data
mg/cig"
CALL   form(mon%,   fc%,   bc%,
title$(),  namtitle$,  5,  x(),
rowstart%,      rowfinish%,
colstart%, formtitle$)
   FOR j = 1 TO 6: emfact(1, j)
= x(j): NEXT j
 CASE 2
  formtitle$ = "K heater data
mg/KJ/jr"
   FOR  j  =  1  TO  6:  x(j)  =
emfact(2, j): NEXT j
  namtitle$   =   "K   heater
pollutant mg/KJ/hr"
   CALL  form(mon%,  fc%,  bc%,
title$(),  namtitle$,  5,  x(),
rowstart%,      rowfinish%,
colstart%, formtitle$)
   FOR j = 1 TO 6: emfact(2, j)
= x(j): NEXT j
  CASE 3
  formtitle$ = "Unvented heater
mg/KJ/hr"
     FOR j = 1 TO 6: x(j) =
emfact(choice%, j): NEXT j
     nametitle$  =  "Unvented
stoves mg/KJ/hr"
   CALL  form(mon%,  fc%,  bc%,
title$(),  namtitle$,  5,  x(),
rowstart%,      rowfinish%,
colstart%, formtitle$)
   FOR    j    =    1    TO    6:
emfact(choice%, j) = x(j): NEXT
j
   CASE 4
   formtitle$ = "Moth crystals
mg/gm"
         namtitle$ = "Moth
crystals mg/g/hr"
         FOR j = 1 TO 6: x(j) = 0:
NEXT j: x(5) = emfact(choice%,
5)
       CALL form(mon%, fc%, bc%,
title$(), namtitle$, 5, x(),
rowstart%, rowfinish%,
colstart%, formtitle$)
      FOR j = 1 TO 6:
emfact(choice%, j) = x(j): NEXT
j
  CASE 5
    formtitle$ = "Floor wax VOC
mg/m2"
    namtitle$ = "Floor wax VOC
mg/m2"
          wtitle$(1) = "Initial
time": wtitle$(2) = "1st
constant": wtitle$(3) = "2nd
constant"
          wtitle$(4) = "3rd
constant": wtitle$(5) = "4th
constant": wtitle$(6) = "5th
constant"
         x(1) = wtime1: x(2) =
wax1: x(3) = wax2: x(4) = wax3:
x(5) = wax4: x(6) = wax5
         CALL form(mon%, fc%, bc%,
wtitle$(), namtitle$, 5, x(),
rowstart%, rowfinish%,
colstart%, formtitle$)
       wtime1 = x(1): wax1 =
x(2): wax2 = x(3): wax3 = x(4):
wax4 = x(5): wax5 = x(6)
  CASE 6
    formtitle$ = "Other source
mg/hr"
    namtitle$ = "Other mg/hr"
         FOR j = 1 TO 6: x(j) =
emfact(choice%, j): NEXT j
       CALL form(mon%, fc%, bc%,
title$(), namtitle$, 5, x(),
rowstart%, rowfinish%,
colstart%, formtitle$)
      FOR j = 1 TO 6:
emfact(choice%, j) = x(j): NEXT
j
  CASE 7
    done = -1
CASE ELSE
 done = -1
END SELECT
WEND
CALL storepdat(title$(),
emfact(), wax1, wax2, wax3,
wax4, wtime1)
END SUB

SUB storepdat (pollutant$(),
pstrength(), wax1, wax2, wax3,
wax4, wtime1) STATIC
REM SET UP POLLUTANT SOURCE
STRENGTHS FOR VARIOUS SOURCES
OPEN "o", 1, "Pollutio.dat"
FOR j = 1 TO 6: PRINT #1,
pollutant$(j): NEXT j
FOR j = 1 TO 6: FOR jk = 1 TO 5:
PRINT #1, pstrength(j, jk): NEXT
jk: NEXT j
PRINT #1, wax1, wax2, wax3,
wax4, wax5, wtime1
CLOSE
END SUB

REM user interface and plot
modules for QuickBasic 4.0
DECLARE FUNCTION rowcol% (row%,
col%)
DECLARE SUB findmax (X!(),
xmax!, xmin!, npoints%)
DECLARE SUB plot (X!(), y!(),
npoints%, xmax!, xmin!, ymax!,
ymin!, room%)
DECLARE SUB getkey (v$, y%)
DECLARE SUB drawx ()
DECLARE SUB drawy ()
DECLARE SUB labelx (xmax, xmin,
ymax, ymin, xstep%, title$)
DECLARE SUB ploty (y!, ymax!,
ymin!, yp!)
DECLARE SUB plotx (X!, xmax!,
xmin!, xp!)
DECLARE SUB ticx (X!, y!)
DECLARE SUB labely (xmax!,
xmin!, ymax!, ymin!, ndec%)
DECLARE SUB plotxy (xplot!(),
yplot!(), npoints%, room%)
DECLARE SUB ticy (X!, y!)
DECLARE SUB box (X%, y%, top$,
btm$, side$)
DECLARE SUB centext (text$,
row%)
DECLARE SUB windmake (mon%, fc%,
bc%, ul%, ur%, ll%, lr%, f%)
DECLARE SUB getmove (curon%, y$,
jy%, row%, col%, cursor$,
blcur$)
DECLARE SUB movecursor (curon%,
row%, col%, dir$, upstep%,
downstep%, leftstep%,
rightstep%)
DECLARE SUB getdata (outans$,
y$, row%, col%)
DECLARE SUB correct (row%, col%,
cans$, jx%)
DECLARE SUB cwind (fc%, bc%,
ur%, uc%, ll%, ar%)
REM $INCLUDE: 'c:\bas\qb.bi'
REM start of user interface
COMMON SHARED /c1/ pollutant$(),
pollutant%, pstrength()
COMMON SHARED /c2/ a(), b(),
c(), d(), calflag%, colr%()
COMMON SHARED /c3/ cigon(),
cigoff(), stoveon(), stoveoff(),
kheaton(), kheatoff(), cookon(),
cookoff(), hour, calstep%,
prntstep%
COMMON SHARED /c4/ maxrooms%,
MAXSOURCES%, maxtimes%,
maxdays%, hrsday, mon%, mon$,
sinkst, deltat
COMMON SHARED /c5/ fc%, bc%,
fracton, endflag, day%, second,
deltain, onecig, xaxismin%
COMMON SHARED /c6/ yaxismin%,
yaxismax%, xaxismax%, xstep%,
ystep%, pthvac
DIM cigon(10), cigoff(10),
stoveon(10, 3), stoveoff(10, 3),
kheaton(10, 3), kheatoff(10, 3),
cookon(10, 3), cookoff(10, 3)
DIM a(10), b(10), c(10), d(10),
colr%(10), pstrength(10, 6),
pollutant$(6)
DEFINT C, J-K, R
DEFSTR A

DEFINT J-K
errhand:
PRINT "ERROR. Please examin
your data and try again.
Returning to program."
FOR jerr = 1 TO 5000: NEXT jerr
RESUME NEXT

DEFSNG A, C, J-K, R
SUB box (X%, y%, top$, btm$,
side$) STATIC
top$ = CHR$(201) + STRINGS$(X% -
2, 205)
btm$ = CHR$(200) + STRINGS$(X% -
2, 205)
REM for j=1 to x%-2:
REM top$=top$+chr$(205)
REM btm$=btm$+chr$(205)
REM next j
top$ = top$ + CHR$(187)
btm$ = btm$ + CHR$(188)
REM for j= 1 to y%-2
R              E              M
side$=side$+chr$(10)+chr$(186)
REM next j
 END SUB

SUB centext (text$, row%) STATIC

 IF LEN(text$) <= 40 THEN LOCATE
row%, 40 - INT(LEN(text$) / 2):
PRINT text$
END SUB

DEFINT J
R              E              M
********************************
********************************
******
SUB correct (row%, col%, cans$,
jx%) STATIC
j1% = LEN(cans$)
IF LEN(cans$) = 0 THEN
    cans$ = ""
    ELSE
  LOCATE row%, col%: PRINT
STRINGS$(10, " ");
   jx% = jx% - 1
   cans$ = LEFTS$(cans$, j1% - 1)
END IF
END SUB

SUB cwind (fc%, bc%, ur%, uc%,
```

```
ll%, ar%) STATIC
DIM inregs AS RegType, outregs
AS RegType
tl% = rowcol(ur% - 1, uc% - 1)
inregs.cx = tl%
tr% = rowcol(ll%, ar%)
inregs.dx = tr%
inregs.ax = &H600
inregs.bx = &H3800
CALL INTERRUPT(&H10, inregs,
outregs)
END SUB

DEFINT K
SUB drawx STATIC
  LINE (xaxismin%,
yaxismax%)-(xaxismax%,
yaxismax%)
END SUB

SUB drawy STATIC
  LINE (xaxismin%,
yaxismax%)-(xaxismin%,
yaxismin%)
END SUB

SUB findmax (X(), xmax, xmin,
npoints%) STATIC
xmax = -1E+20
xmin = 1E+20
FOR j% = 1 TO npoints%
 IF X(j%) > xmax THEN xmax =
X(j%)
 IF X(j%) < xmin THEN xmin =
X(j%)
NEXT j%
END SUB

DEFSNG J-K
SUB form (mon%, fc%, bc%,
title$(), namtitle$, numtitles%,
valx(), rowstart%, rowfinish%,
colstart%, formtitle$) STATIC
DEFINT J
CLS
CALL windmake(mon%, fc%, bc%, 2,
2, 20, 78, 0)
LOCATE 1, 40: PRINT "|";
cur$ = "-" + CHR$(16)
CALL box(4 + LEN(formtitle$), 5,
top$, btm$, side$)
CALL centext(top$, 1):
side$ = CHR$(186) +
STRINGS$(LEN(top$) - 2, " ") +
CHR$(186)
FOR j = 1 TO 3
CALL centext(side$, 1 + j)
NEXT j
CALL centext(btm$, 4)
CALL centext(formtitle$, 2)
LOCATE 25, 10: PRINT "Use arrow
keys to move cursor Press ESC to
return.";
LOCATE 6, 3: PRINT STRINGS$(74,
"=")
LOCATE 7, 10: PRINT namtitle$:
LOCATE 7, 50: PRINT "Value"
LOCATE 8, 3: PRINT STRINGS$(74,
"=")
jmin% = rowstart%
row% = rowstart%: col% =
colstart%
FOR j = 1 TO numtitles%
  LOCATE row%, col%: PRINT
title$(j);
  LOCATE row%, col% + 40: PRINT
valx(j);
  row% = row% + 1:
NEXT j
row% = rowstart%: col% =
colstart%
y$ = "1"
WHILE ASC(y$) <> 27
COLOR fc%, bc%
LOCATE row%, col% - 5: PRINT
cur$;
 LOCATE row%, col%: COLOR bc%,
fc%: PRINT STRING$(30, " ");
 LOCATE row%, col%: COLOR bc%,
fc%: PRINT title$(row% -
rowstart% + 1);
 LOCATE row%, col% + 40: PRINT
valx(row% - rowstart% + 1);
CALL getmove(0, y$, jy%, row%,
col% - 5, cur$, "- ")
IF ASC(y$) <> 27 THEN
IF LEN(y$) = 2 THEN
 LOCATE row%, col%: COLOR fc%,
bc%: PRINT STRING$(30, " ");
 LOCATE row%, col%: PRINT
title$(row% - rowstart% + 1);
 LOCATE row%, col% + 40: PRINT
valx(row% - rowstart% + 1);
 IF RIGHT$(y$, 1) = "P" THEN
  CALL movecursor(0, row%, col%
- 5, "D", 1, 1, 0, 0)
  IF row% > rowfinish% THEN row%
= rowstart%
  ELSEIF RIGHT$(y$, 1) = "H"
THEN
  CALL movecursor(0, row%, col%
- 5, "U", 1, 1, 0, 0)
  IF row% < rowstart% THEN row%
= rowfinish%
  ELSE
   dir$ = ""
 END IF
 ELSE
 LOCATE row%, col% - 5: PRINT "
";
 LOCATE row%, col% + 40: COLOR
bc%, fc%: PRINT STRING$(10, "
");
 COLOR fc%, bc%
 CALL getdata(X$, y$, row%, col%
+ 41)
 valx(row% - rowstart% + 1) =
VAL(X$)
 COLOR fc%, bc%
 LOCATE row%, col% + 40: PRINT
STRING$(10, " ");
 LOCATE row%, col% + 40: PRINT
valx(row% - rowstart% + 1);
 LOCATE row%, col% - 5: PRINT
cur$;
 END IF
```

```
 END IF
WEND
END SUB

SUB getdata (outans$, y$, row%,
col%) STATIC
col1% = col%
 ans$ = y$
 LOCATE row%, col%: PRINT ans$;
  WHILE ASC(y$) <> 13
 CALL getkey(y$, y%)
 IF LEN(y$) = 2 THEN
 y% = 13
 y$ = CHR$(13)
 END IF
 IF y% <> 13 THEN
 IF y% = 8 THEN
 CALL correct(row%, col1%, ans$,
col1%)
   ELSE
     col1% = col1% + 1
     LOCATE row%, col1%: PRINT
y$;
     ans$ = ans$ + y$
END IF
END IF
 WEND
 outans$ = ans$
END SUB

SUB getkey (y$, y%) STATIC
IF calflag% <> -1 THEN
y$ = ""
WHILE y$ = ""
y$ = INKEY$
WEND
 ELSE
 y$ = CHR$(27)
calflag% = 0
END IF
y% = ASC(y$)
END SUB

SUB getmove (curon%, y$, jy%,
row%, col%, cursor$, blcur$)
STATIC
IF calflag% <> -1 THEN
y$ = ""
y$ = INKEY$
WHILE y$ = ""
 IF curon% = 0 THEN
  LOCATE row%, col%: PRINT
cursor$;
  LOCATE row%, col%: PRINT
blcur$;
 END IF
  y$ = INKEY$
  IF calflag% = -1 THEN
  y$ = CHR$(27)
  calflag% = 0
  END IF
WEND
ELSE
 calflag% = 0
  y$ = CHR$(27)
  END IF
IF LEN(y$) = 2 THEN jy% =
ASC(RIGHT$(y$, 1)) ELSE jy% =
ASC(y$)                              F
I
INSTR("abcdefghijklmnopqrstuvwx
yz", y$) <> 0 THEN y$ = CHR$(jy%
- 32)
END SUB

DEFINT K
SUB labelx (xmax, xmin, ymax,
ymin, xstep%, title$) STATIC
xoff% = xaxismin% / xstep%
LOCATE 24, 40 - LEN(title$) / 2:
PRINT title$;
LOCATE yaxismax% / ystep% + 2,
xaxismin% / xstep%: PRINT USING
"#.#"; xmin * 2.77778E-04;
CALL ploty(ymin, ymax, ymin, y)
X = xmin
xs = (xmax - xmin) / 10
FOR j = 1 TO 11
xz = X * 2.77778E-04
z$ = STR$(xz)
s = INT(LEN(z$) / 2 + .65)
xl = xl + xls
CALL plotx(X, xmax, xmin, xp)
LOCATE yaxismax% / ystep% + 2,
xp / xstep% - s: PRINT USING
"###.#"; xz;
CALL ticx(xp, y)
X = X + xs
NEXT j
LOCATE 23, xaxismax% / xstep% -
1: PRINT USING "###.#"; xmax *
2.77778E-04;
END SUB

SUB labely (xmax, xmin, ymax,
ymin, ndec%) STATIC
a$ = "#"
y = ymin: CALL plotx(xmin, xmax,
xmin, X)
IF ndec% > 15 THEN
   labstep% = ndec%
   ELSEIF ndec% > 10 THEN
   labstep% = 2
 ELSE
 labstep% = 1
 END IF
FOR j = 1 TO ndec% + 1
CALL ploty(y, ymax, ymin, yp)
CALL ticy(X, yp)
y = y + 1
NEXT j
y = ymin
IF mon$ = "EGA" THEN
   yj = 14
   ya = 1.1
   ELSE
   yj = 7.6
   ya = 0
END IF
FOR j = 1 TO ndec% STEP labstep%

CALL ploty(y, ymax, ymin, yp)
CALL ticy(X, yp)
ylab = 10 ^ y
IF y < 0 THEN a2$ = a$ + "." +
STRING$(ABS(y), a$) ELSE a2$ =
STRING$(y + 1, a$)
LOCATE INT(yp / yj + ya), 6:
PRINT USING a2$; ylab;
y = y + labstep%
NEXT j
IF ymax < 0 THEN a2$ = a$ + "."
+ STRING$(ABS(ymax), a$) ELSE
a2$ = STRING$(ymax + 1, a$)
LOCATE 2, 6: PRINT USING a2$; 10
^ ymax;
LOCATE 4, 1: PRINT "C";
LOCATE 5, 1: PRINT "o";
LOCATE 6, 1: PRINT "n";
LOCATE 7, 1: PRINT "c";
LOCATE 8, 1: PRINT ".";
LOCATE 9, 1: PRINT "";
LOCATE 10, 1: PRINT "m";
LOCATE 11, 1: PRINT "g";
LOCATE 12, 1: PRINT "7";
LOCATE 13, 1: PRINT "m3";
LOCATE 14, 1: PRINT "";
LOCATE 15, 1: PRINT "";
LOCATE 16, 1: PRINT "";
END SUB

DEFSNG K
R               E               M
*******************************
****************************
SUB menu (fc%, bc%, ok$,
title$(), rows%, newrow%, cols%,
nrows%, menutitle$, choice%)
STATIC
CLS
cflag% = 1
cur$ = ""
CALL box(5 + LEN(menutitle$), 5,
top$, btm$, side$)
CALL centext(top$, 2)
CALL centext(btm$, 7)
side$ = CHR$(186) +
STRING$(LEN(top$) - 2, " ") +
CHR$(186)
FOR j = 1 TO 4
CALL centext(side$, 2 + j)
NEXT j
CALL centext(menutitle$, 5)
row% = rows%
col% = cols%
LOCATE 24, 1: PRINT "Use arrow
keys to move cursor.  Press
ENTER to execute.  ESC to
return.";
FOR j = 1 TO nrows%
  LOCATE row%, cols%: PRINT
title$(j);
  row% = row% + 1
  NEXT j
row% = rows% + newrow% - 1
cols% = col%
y$ = "1"
WHILE ASC(y$) <> 13
COLOR fc%, bc%
 LOCATE row%, col% - 3: PRINT
cur$;
 LOCATE row%, col%: COLOR bc%,
fc%: PRINT
STRING$(LEN(title$(row% - rows%
+ 1)), " ");
 LOCATE row%, col%: COLOR bc%,
fc%: PRINT title$(row% - rows% +
1);
 CALL getmove(0, y$, jy%, row%,
col%, cur$, "")
 IF INSTR(ok$, y$) = 0 THEN
 IF ASC(y$) <> 27 THEN
IF ASC(y$) <> 13 THEN
 IF LEN(y$) = 2 THEN
 LOCATE row%, col%: COLOR fc%,
bc%: PRINT STRING$(30, " ");
 LOCATE   row%,   col%:   PRINT
title$(row% - rows% + 1);
 IF RIGHT$(y$, 1) = "P" THEN
  CALL movecursor(0, row%, col%
- 3, "D", 1, 1, 0, 0)
  IF row% > rows% + nrows% - 1
THEN row% = rows%
  ELSEIF  RIGHT$(y$,  1)  =  "H"
THEN
  CALL movecursor(0, row%, col%
- 3, "U", 1, 1, 0, 0)
  IF row% < rows% THEN row% =
rows% + nrows% - 1
  ELSE
   dir$ = ""
END IF
END IF
END IF
ELSE
 row% = nrows% + rows%
 y$ = CHR$(13)
END IF
ELSE
choice% = INSTR(ok$, y$)
cflag% = -1
y$ = CHR$(13)
END IF
WEND
IF  cflag%  =  1  THEN  choice% =
row% - rows% + 1 ELSE choice% =
choice%
COLOR fc%, bc%
END SUB

SUB  movecursor  (curon%,  row%,
col%, dir$, upstep%, downstep%,
leftstep%, rightstep%) STATIC
IF curon% = 0 THEN LOCATE row%,
col%: PRINT "  ";
IF dir$ = "U" THEN row% = row% -
upstep%
IF dir$ = "L" THEN col% = col% -
leftstep%
IF dir$ = "R" THEN col% = col% +
rightstep%
IF dir$ = "D" THEN row% = row% +
downstep%
END SUB

DEFINT K
SUB  plot  (X(),  y(),  npoints%,
xmax, xmin, ymax, ymin, room%)
STATIC
FOR j = 1 TO 10000: NEXT j
24900   REDIM   yplot(npoints%),
xplot(npoints%)
```

```
IF  mon$  =  "EGA"  THEN  SCREEN  9
ELSE SCREEN 2
ndec% = ABS(ymax - ymin)
CALL  labely(xmax,  xmin,  ymax,
ymin, ndec%)
CALL  labelx(xmax,  xmin,  ymax,
ymin, xstep%, "Time Hrs")
FOR j% = 1 TO npoints%:
25000  CALL  ploty(y(j%),  ymax,
ymin, yplot(j%))
25100  CALL  plotx(X(j%),  xmax,
xmin, xplot(j%))
NEXT j%
CALL drawx
CALL drawy
CALL  plotxy(xplot(),  yplot(),
npoints%, room%)
END SUB

DEFSNG J-K
SUB  plotem  (X(),  z(),  tmax%,
nrooms%) STATIC
REDIM y(tmax%)
DEFINT J-K
REM ON ERROR GOTO errhand
yymin = 1E+29
yymax = -1E+29
xxmax = 1E+29
xxmin = 1E+29
alog = LOG(10)
CLS
PRINT "Setting up plot"
rs% = 0
FOR room% = rs% TO nrooms%
 FOR j = 0 TO tmax%
      IF conc > 0 THEN
       IF z(1, room%, j) <= conc
THEN z(1, room%, j) = conc
      ELSE
      IF z(1, room%, j) <= .001
THEN z(1, room%, j) = .001
      END IF
   y(j) = LOG(z(1, room%, j)) /
alog
 NEXT j
FOR j = 2 TO tmax%:
IF X(j) < X(j - 1) THEN EXIT FOR

NEXT j
tmax% = j - 1
CALL  findmax(y(),  ymax,  ymin,
tmax%)
IF ymax = ymin THEN ymax = ymin
+  1:   REM   cover   order   of
magnitude
xmax = X(tmax%): xmin = 0
IF  xmax  <  xxmax  THEN  xxmax  =
xmax
IF  ymax  >  yymax  THEN  yymax  =
ymax
IF  ymin  <  yymin  THEN  yymin  =
ymin
IF  xmin  <  xxmin  THEN  xxmin  =
xmin
NEXT room%
IF  INT(xxmax  *  2.77778E-04)  -
xxmax  *  2.77778E-04  <>  0  THEN
xxmax = INT(xxmax * 2.77778E-04
+ .9999) * 3600
IF mon$ = "EGA" THEN
SCREEN 9
PALETTE 8, 2
ELSE
SCREEN 2
END IF
WIDTH 80
IF yymin < -3 THEN yymin = -3
yymin  =  INT(yymin):  yymax  =
INT(yymax + .995)
LOCATE 1, 30: PRINT "Plot for ";
pollutant$(pollutant%);
ymax = yymax
ymin = yymin
xmax = xxmax
xmin = xxmin
FOR j% = rs% TO nrooms%
 FOR k = 1 TO tmax%
    y(k)  =  LOG(z(1,  j%,  k))  /
alog
   NEXT k
 CALL  plot(X(),  y(),  tmax%,
xmax, xmin, ymax, ymin, j%)
 IF colr%(2) = 1 THEN
   IF j% = 0 THEN t1$ = "HVAC"
ELSE t1$ = "Room " + STR$(j%)
   LOCATE 25, 20: PRINT t1$; "
press any key to continue";
   CALL getkey(y$, y%)
 END IF
NEXT j%
 IF colr%(2) > 1 THEN
 LOCATE 25, 1: PRINT STRING$(79,
" ");
 LOCATE 25, 1: COLOR colr%(0):
PRINT "HVAC"; " ";
 FOR j = 1 TO nrooms%: COLOR
colr%(j): PRINT j; "  "; : NEXT
j
 LOCATE 25, 50: PRINT "Press any
key ";
 CALL getkey(y$, y%)
END IF
END SUB

SUB plotx (X, xmax, xmin, xp)
STATIC
 xp = xaxismin% + (X - xmin) *
(xaxismax% - xaxismin%) / (xmax
- xmin)
END SUB

SUB plotxy (xplot(), yplot(),
npoints%, room%) STATIC
DEFINT J
REM  yplot(1),xplot(1)
FOR j = 2 TO npoints%
  LINE (xplot(j - 1), yplot(j -
1))-(xplot(j),   yplot(j)),
colr%(room%)
 PSET (xplot(j), yplot(j))
 NEXT j
 END SUB

SUB ploty (y, ymax, ymin, yp)
STATIC
yp = yaxismax% - (y - ymin) *
(yaxismax% - yaxismin%) / (ymax
- ymin)
END SUB

DEFINT C, R
DEFSTR A
FUNCTION rowcol (row%, col%)
a1$ = HEX$(row%)
a2$ = HEX$(col%)
IF LEN(a2$) = 1 THEN a2$ = "0" +
a2$
rowcol = VAL("&H" + a1$ + a2$)
END FUNCTION

DEFSNG A, C, R
SUB ticx (X, y) STATIC
 LINE (X, y)-(X, y - 3)
 END SUB

 SUB ticy (X, y) STATIC
 LINE (X, y)-(X + 3, y)
 END SUB

DEFSNG K
SUB  windmake  (mon%,  fc%,  bc%,
ul%, ur%, ll%, lr%, f%) STATIC
CALL  cwind(fc%,  bc%,  ul%  -  1,
ur%, ll%, lr%)
 IF f% = -1 THEN COLOR bc%, fc%
ELSE COLOR fc%, bc%
 cstep% = lr% - ur% - 2
 nr% = ll% - ul% - 1
 CALL box(lr% - ur%, ll% - ul%,
top$, btm$, side$)
 DEF SEG = mon%
 c%  =  ur%:  FOR  j%  =  1  TO
LEN(top$):
 POKE 160 * (ul% - 2) + 2 * (c%
- 1), ASC(MID$(top$, j%, 1))
 POKE 160 * (ll% - 2) + 2 * (c%
- 1), ASC(MID$(btm$, j%, 1)): c%
= c% + 1
 NEXT j%
 DEF SEG
REM locate ul%-1,ur%:print top$;

REM locate ll%-1,ur%:print btm$;

 r1% = ul%: c% = ur%
 DEF SEG = mon%
FOR j% = 1 TO nr%:
REM    locate    r1%,c%:print
wc$:r1%=r1%+1
 POKE 160 * (r1% - 1) + 2 * (c%
- 1), 186: POKE 160 * (r1% - 1)
+ 2 * (c% + cstep%), 186
 r1% = r1% + 1
 NEXT j%
DEF SEG
END SUB
```

APPENDIX B

CONTENTS OF DOCUMENTATION FILES

This is version 1.0 of the AEERL indoor air model.
The program is configured for a monochrome display.
If you have a color graphics board or an EGA board you should reconfigure the program for your hardware. You can do this by:

1. Typing INDOOR to load and execute the program.
2. Selecting Configure computer option from the menu.
3. Following the on-screen instructions to reconfigure the program for your hardware.
4. Being sure to save your new configuration file.

You can install the program on your hard disk by typing INSTALL. INSTALL will create a subdirectory called INDOOR on your hard disk and will copy all the necessary files from this disk to the INDOOR subdirectory.

Guidance on selecting air flow rates:
Common HVAC systems produce 6-7 air changes per hour (ACH) in each room.

Flow through an open door without HVAC is between 3 and 5 ACH in both directions. For example, assume two rooms each with a volume of 30 cubic meters. The flow from room 1 to room 2 might be on the order of 100 cubic meters per hour and the flow from room 2 to room 1 would be the same.